

Predislocation Syndrome

Progressive Subluxation/Dislocation of the Lesser Metatarsophalangeal Joint

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Progressive subluxation/dislocation of the lesser toes resulting from idiopathic inflammation about one or more of the lesser metatarsophalangeal joints is a common cause of metatarsalgia that is frequently unrecognized or misdiagnosed. The disorder results from a failure of the plantar plate and collateral ligaments that stabilize the metatarsophalangeal joints and is typically associated with abnormal forefoot loading patterns. The authors refer to this condition as predislocation syndrome and have devised a clinical staging system that is based on the clinical signs and symptoms present during examination. A thorough review of predislocation syndrome and an overview of the conservative and surgical treatment options available for this disorder are presented. (*J Am Podiatr Med Assoc* 92(4): 182-199, 2002)

Painful instability of the lesser metatarsophalangeal joint has been recognized in both the orthopedic and the podiatric literature as a common cause of metatarsalgia.¹⁻⁶ The condition is typically described as a progressive, painful subluxation or dislocation of the proximal phalangeal base on the metatarsal head that occurs as a result of weakening of the periarticular structures that stabilize the metatarsophalangeal joint—in particular, the plantar plate. The subluxation/dislocation process can be slow or rapidly progressive. Medial or, less commonly, lateral deviation of the digit may also occur and accompanies dorsal

migration of the proximal phalanx. A hammer toe deformity may be found in association with the disorder, but is usually not an early or a significant component. Unlike in the classic hammer toe deformity, a dorsal corn overlying the proximal interphalangeal joint is typically not observed (Fig. 1). Although any lesser metatarsophalangeal joint can be affected, the second metatarsophalangeal joint is affected most often.^{7,8} Hallux valgus and first-ray insufficiency may contribute to this problem but are not necessarily precursors or prerequisites.¹⁻⁶ A long second metatarsal has also been implicated in the development of this entity.¹

While pain about any lesser metatarsophalangeal joint may be associated with several systemic and local processes, the idea of idiopathic pain and instability of the metatarsophalangeal joint is relatively new.^{6,9} The literature is replete with numerous terms describing the components of lesser toe derangement. The following terms, for example, are slightly modified from a list appearing in Miller¹⁰:

- Sub-metatarsal 2/neuroma syndrome
- Chronic lesser metatarsophalangeal dislocation

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Figure 1. Classic hammer toe deformity of the second toe with chronic metatarsophalangeal joint subluxation. Note the presence of a classic heloma durum overlying the proximal interphalangeal joint, which is not typically seen in patients with predislocation syndrome.

- Floating toe syndrome
- Lesser metatarsophalangeal joint instability syndrome
 - Second metatarsophalangeal joint dislocation/subluxation
 - Monoarticular nontraumatic synovitis of the second metatarsophalangeal joint
 - Crossover second-toe deformity
 - Second metatarsophalangeal joint instability

The authors, however, consider many of these to be part of a distinct clinical entity, which they refer to as predislocation syndrome. Once a frank dislocation occurs, more appropriate descriptive terminology should be employed. This article presents the natural history of predislocation syndrome and reviews the conservative and surgical treatment options available for this disorder.

Clinical Presentation

Patients suffering from predislocation syndrome typically present with acute, subacute, or, less commonly, chronic focal pain at the plantar aspect of the involved lesser metatarsophalangeal joint or joints. In general, pain is most noticeable during ambulation and subsides during rest.¹¹ Frequently, patients com-

plain that they feel as if they are walking on a “stone bruise” or “lump” on the bottom of the foot in spite of the absence of any obvious plantar lesion. Patients may also complain of swelling about the base of the toe, more impressive plantarly than dorsally. Some patients will note that the toe “feels as though it is trying to go out of position,” and others may have even noted a distinct change in position over the course of several weeks. Rarely is a lesion present over the dorsal aspect of the proximal interphalangeal joint, although mild erythema may be present as a result of shoe irritation of the knuckle pad. Tyloma formation plantarly is rarely present.

Some patients mention a recent increase or change in activity level prior to the development of symptoms.¹ The current authors have seen this problem develop following participation in such activities as jogging, tennis, and basketball. In other cases, patients may recall a minor traumatic event, such as a misstep on a stair, hole, or protruding object such as a garden hose or an electrical cord prior to the development of symptoms. In a number of cases, the senior author (G.V.Y.) has encountered a history of a misstep climbing up or down stairs or a ladder as an inciting factor.

In later stages of predislocation syndrome, severe pain may lead to an antalgic gait, with the patient compensating by walking on the lateral aspect of the foot. Barefoot weightbearing often becomes intolerable, especially on hard surfaces. The authors have found that secondary manifestations, such as lateral column overload and calcaneocuboid joint syndrome, may occur, sometimes becoming as significant as the original chief presenting complaint. A constant lingering or long-lasting throbbing sensation may also develop, regardless of weightbearing status.

Frequently, the patient had sought treatment for the problem in the past, often after being treated by a variety of medical and surgical specialists to no avail. Treatments may have been either conservative or surgical. It is not uncommon for the patient to have received a diagnosis of second interspace or adjacent interspace neuromas in spite of the obvious absence of the subjective complaints classically associated with neuromas. Many patients will have undergone neurectomy, some with revisional procedures undertaken for the presumed recurrence of neuroma or stump neuroma (Fig. 2). The failure of these various treatments and continuing disability are very frustrating for patients and may give rise to anxiety about their prognosis.⁶ Some patients may have been accused of malingering or suspected of having a psychosomatic illness. A few patients or their spouses may even question whether they are imagining the

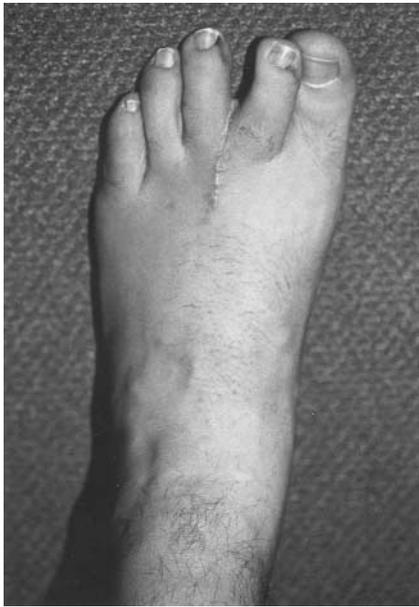


Figure 2. Foot of a 45-year-old patient who previously underwent two neuroma resections from the second interspace within a 3-month period. This patient subsequently developed complete dislocation of the second metatarsophalangeal joint. Note the persistent swelling of the second metatarsophalangeal joint and toe. The patient denied having had the symptoms attributable to a typical neuroma.

problem and feel as if they are acting like hypochondriacs. Some patients, out of desperation, will plead, "Please tell me I'm not crazy!" Not uncommonly, this unfortunate chain of events results in significant depression and anxiety, further complicating the clinical course of the complaint.

Physical Examination

Specific and accurate pain localization during a physical examination is paramount for determining the structures affected. On physical examination of the patient with predislocation syndrome, one finds excruciating pain on palpation just distal and plantar to the metatarsal head that is disproportionate to any other objective clinical findings. Focal pain in this area is thought to result from bursitis or inflammation of the plantar plate.¹² Occasionally, inflammation of an intermetatarsal bursa may cause local nerve irritation, resulting in neuritic or neuroma-type symptoms. However, patients presenting with pain caused by inflammation of the plantar plate generally do not have subjective complaints of numbness or shooting pain or objective sensory deficits in the affected digits on clinical examination.¹¹ In addition, on physical

examination, the focal point of tenderness is clearly and distinctly the metatarsophalangeal joint area, not the adjacent interspace. An intermetatarsal injection of local anesthetic may be helpful when symptoms are generalized or when the patient has difficulty pinpointing the target area of pain.

Active flexor and extensor tendon functions of the affected toe are present with minimal or no compromise. Palpation and range of motion of the metatarsophalangeal joint may elicit capsular crepitus or mobility of a well-circumscribed, bursa-like projection. A painful decrease in range of motion of the joint, particularly in plantarflexion, is often noted.¹³ Significant malposition is absent in the early stages; however, the astute clinician readily notes subtle changes in position over time. Not uncommonly, the toe manifests a clear tendency toward dorsal migration (not necessarily dorsiflexion), with or without transverse plane deviation toward or away from the hallux (Fig. 3).

In most cases, evaluation of weightbearing stance demonstrates subtle but obvious malalignment of the involved digit. Loss of toe purchase, with or without medial or lateral deviation, is typically present. If this condition is left unchecked, the toe will continue to progressively subluxate dorsally, and when this occurs, increased pain plantarly is predictable. Rarely, a callus plantar to the metatarsal head or a corn overlying the proximal interphalangeal joint of the affected toe (as is typically seen with the classic hammer toe deformity that has undergone chronic metatarsophalangeal joint subluxation/dislocation) is present on examination. These keratoses are due to friction and shear of associated osseous structures and to loss of intrinsic muscle balance; they develop only after long-standing dislocation of the toe.

Change in local topography is common and often impressive (Fig. 4). Local edema and warmth resulting from inflammation about the metatarsophalangeal joint are typically present; the increased temperature may be measured with skin-surface thermometers and recorded. Subtle edema may be indicated by the obliteration of normal extensor tendon contours. In most cases, the plantar edema is obvious, even profound, and encompasses the entire metatarsophalangeal joint area, frequently extending distally into the sulcus and base of the toe or toes.

In the initial stages of predislocation syndrome, the lesser metatarsophalangeal joint may be in good anatomical position without malalignment or contracture. However, as the condition progresses and joint instability ensues, dorsal or transverse plane deviation develops, with subsequent loss of toe purchase. The stages of predislocation syndrome have



Figure 3. Nonweightbearing (A) and weightbearing (B) views of a patient with predislocation syndrome of the right second toe. Note the edema surrounding the metatarsophalangeal joint, obliteration of the extensor tendons to the second digit, and the absence of a significant lesion over the proximal interphalangeal joint. Mild irritation is present. Absence of toe purchase and medial deviation are seen on weightbearing.

been described by Yu and Judge⁶ and are based on the clinical findings present at the time of examination. In stage 1, there is mild edema plantar, and often dorsal, to the metatarsophalangeal joint. Extreme tenderness is present when the joint is manipulated. No anatomical malalignment is noted clinically. In stage 2, there is moderate edema with noticeable deviation of the affected digit both clinically and radiographically. Often the patient does not realize that the affected toe does not purchase the ground. This becomes quite evident in stance evaluation. In stage 3, moderate edema is present about the entire circumference of the metatarsophalangeal joint and ex-

tends into the toe. More pronounced deviation and possible subluxation/dislocation of the toe are present. While the edema and inflammation eventually subside altogether, the deformity remains unchanged or continues to progress. The end result can be a crossover second-toe deformity, with or without a concomitant hallux abducto valgus deformity.

Thompson and Hamilton⁵ have suggested the use of a vertical stress test, akin to the anterior drawer sign in the unstable ankle joint, to identify and stage sagittal plane metatarsophalangeal joint instability. In this maneuver, the foot is placed in neutral position, and the metatarsal head is stabilized between the examiner's thumb and index finger. The contralateral hand is used to grip the dorsal and plantar aspect of the corresponding proximal phalanx base. The digit to be tested is manipulated upward with vertical pressure applied by the thumb plantarly. A purely vertical force is applied to the base of the proximal phalanx in the dorsal direction. This is different from testing for dorsiflexion (Fig. 5). A positive vertical stress test result is present when the proximal phalanx can be translocated 2 mm dorsally above the metatarsal head. According to Thompson and Hamilton's classification scheme, in stage 0 there is no dorsal translocation of the proximal phalanx. In stage 1, the phalangeal base can undergo subluxation dorsally but not dislocation. In stage 2, the phalangeal base can be dislocated but may be manually reduced. In stage 3, the phalangeal base is in a fixed dislocated position. Accurate assessment of the amount of dislocation of the base of the proximal phalanx on the metatarsal head may be quantified on a lateral x-ray.



Figure 4. Edema in a patient with predislocation syndrome of the left third metatarsophalangeal joint. The patient has a congenital syndactyly of the second and third digits, confusing the clinical presentation. Note the absence of similar findings in the contralateral foot.



Figure 5. Positive vertical stress test result with dorsal translocation of the proximal phalanx. Note maintenance of the toe parallel to the plantar aspect of the foot while this maneuver is performed. The examiner must be careful not to confuse dorsal translocation with dorsiflexion.

A thorough history and physical examination are required to rule out all systemic and local problems that may contribute to pain about the metatarsophalangeal joint. Degenerative joint disease, avascular necrosis, rheumatoid arthritis, fat pad atrophy, stress fracture, neuromuscular dysfunction, and neuromas are all common causes of lesser metatarsalgia.^{2, 12} Only after a detailed history and physical examination and a radiographic evaluation can a primary diagnosis of predislocation syndrome be made (Table 1). Selective laboratory testing may be needed for completeness. It is important to listen carefully to the patient's subjective complaints, as these will often provide sufficient information for the clinician to suspect this entity as the cause of the patient's pain, even prior to a physical examination of the area.

Pathomechanics

The key developmental factor for idiopathic subluxation/dislocation of the lesser toe is progressive inflammation about the metatarsophalangeal joint with subsequent attenuation and rupture of the plantar plate and collateral ligaments.^{2, 5} Thus any structural or biomechanical deformity that increases loading forces within the forefoot and results in inflammation of the plantar plate can predispose an individual to progressive weakening of the periarticular structures and resultant joint instability.

A long second metatarsal is often cited as a common finding in individuals with instability of the second metatarsophalangeal joint.^{8, 11} An elongated sec-

ond metatarsal (or a short first metatarsal) may alter normal forefoot loading patterns by transferring load from the first to the second metatarsal head (Fig. 6). Hallux abducto valgus may also cause abnormal forefoot loading patterns.² Lateral deviation of the hallux into the second digit may cause multiplanar deviation of the second toe that results in retrograde buckling at the second metatarsophalangeal joint level on weightbearing. The use of high-heeled shoes or heel lifts, which increase forefoot loading by maintaining the metatarsophalangeal joints in a hyperextended position, have also been implicated in the development of predislocation syndrome in one or more of the lesser digits.¹

Biomechanical hypermobility may also predispose a patient to altered forefoot loading patterns. Excessive pronation will alter the axis of insertion of the peroneus longus tendon in such a way that it loses its ability to stabilize the first ray during the forefoot-loading phase of gait.¹³ Accordingly, metatarsus primus elevatus resulting from either biomechanical dysfunction or structural deformity may cause excessive load transfer to the adjacent lesser metatarsophalangeal joint or joints. Similarly, first-ray insufficiency caused by generalized joint hypermobility syndromes, such as Ehlers-Danlos syndrome or Marfan syndrome, may result in overload of one or more of the lesser metatarsophalangeal joints.¹⁴

The senior author has also witnessed numerous cases of predislocation syndrome in patients who had undergone surgical correction of hallux abducto valgus deformity in which subtle, but discernible, elevation of the first metatarsal head occurred (Fig. 7). In other cases, the initial presenting complaint was sub-metatarsal 2 discomfort attributed to an asymptomatic hallux abducto valgus deformity. While surgery for the hallux abducto valgus was uneventful, progressive dislocation of the second toe ensued. Patient frustration in such cases is very high.

Coughlin¹ has identified two distinct populations at risk for developing instability of the second metatarsophalangeal joint: The first group consisted mainly of sedentary women aged 50 to 70 years, with an average age of 60 years. The high proportion of elderly women in this group was attributed to the prevalent use of high-heeled shoes in this population. The second group consisted predominantly of athletic men aged 25 to 64 years, with an average age of 50 years. A majority of this group were found to have a long second metatarsal. Coughlin hypothesized that in the second group repetitive physical activity resulted in inflammation about the second metatarsophalangeal joint that eventually resulted in a weakening of the periarticular structures that stabilize the

Table 1. Differentiating Predislocation Syndrome from Common Lesser Metatarsophalangeal Joint Problems

Predislocation Syndrome	Other Common Problems
Pain localized to plantar metatarsophalangeal joint	<u>Stress Fracture</u> Pain at metatarsal shaft dorsally
Negative tuning fork test	Tuning fork test elicits pain
X-rays nondiagnostic in early stages	Conventional x-rays eventually diagnostic
Bone scan uptake at metatarsophalangeal joint	Bone scan uptake in metatarsal shaft
Minor trauma or inciting event may be recalled	<u>Hammer Toe</u> No inciting event or trauma
Onset distinctly acute, subacute, or chronic	Onset insidious over years
No digital contracture until late stage	Contracture at proximal or distal interphalangeal joint preceded pain
Positive vertical drawer test	Negative vertical drawer test
Usually no lesions; occasional irritation of the dorsal proximal interphalangeal joint	Lesions frequently present: heloma durum at proximal interphalangeal joint and/or sub-metatarsal head tyloma
Plantar to metatarsophalangeal joint, often the second interspace	<u>Neuroma</u> Classic third interspace
Neuritic symptoms absent	Neuritic symptoms: tingling, cramping, burning, shooting pain
Moulder sign absent	Positive Moulder sign: palpable click of soft-tissue mass
Subtle or obvious malalignment or malposition of the involved toes	Toes usually have normal alignment and position
May demonstrate significant inflammation of metatarsophalangeal joint and toe, especially plantarly	No edema present

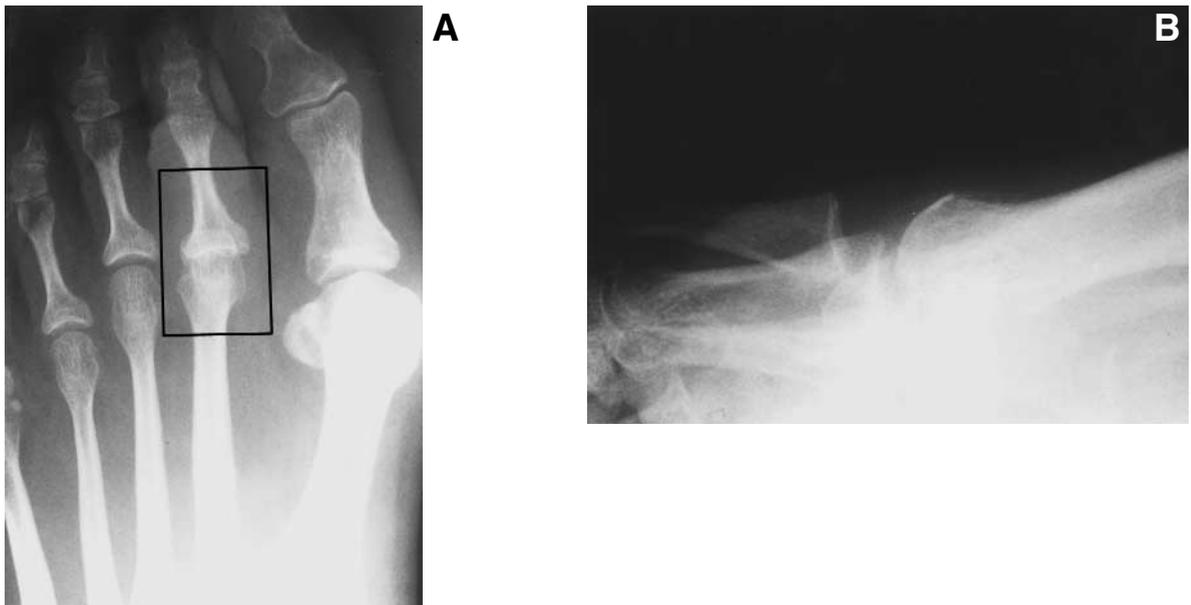


Figure 6. Anteroposterior (A) and lateral (B) radiographs of a patient who developed sudden dislocation of the second metatarsophalangeal joint following a period of severe pain and inflammation of the plantar aspect of the joint. Note the slightly elongated second metatarsal segment as a possible contributing factor and the presence of a hallux abducto valgus deformity.



Figure 7. Anteroposterior (A) and lateral (B) radiographs demonstrating dorsal dislocation of the second toe following a distal metaphyseal osteotomy for correction of a hallux abducto valgus deformity. The patient's initial complaint was pain beneath the second metatarsal segment. An arthroplasty procedure was performed. Owing to persistent symptoms, the patient received multiple injections of steroid and local anesthetic, which resulted in acceleration of the deformity and a steroid-induced avascular necrosis of the third proximal phalangeal base. Note the development of a stress fracture of the second metatarsal and the shortening and elevation of the first metatarsal segment.

toe. The authors believe that both structural alteration and biomechanical dysfunction of the first ray can contribute to the development of this entity at the second metatarsophalangeal joint. The condition can, however, occur in the absence of either of these predisposing factors.

Role of the Plantar Plate in Predislocation Syndrome

Stability of the lesser metatarsophalangeal joint is derived from the plantar plate, the collateral ligaments, and the intrinsic and extrinsic foot musculature.¹⁵⁻¹⁷ Static stabilization of the metatarsophalangeal joint is derived primarily from the plantar plate and collateral ligaments. The plantar plate is described as a fibrocartilaginous thickening of the metatarsophalangeal joint capsule plantarly that is firmly attached to the base of the proximal phalanx but only loosely attached to the metatarsal head.¹⁵ It is composed of type I collagen that is histologically identical to the collagen present in the meniscus of the knee.¹⁶ The plantar plate acts as the major distal attachment of the plantar fascia and has attachments to the deep transverse metatarsal ligament and metatarsophalangeal joint collateral ligaments. It

also serves as an insertion for both the interosseous and the lumbrical tendons. Inferiorly, the plantar plate has a smooth grooved surface for the passage of the flexor tendons.

An anatomical dissection by Johnston et al¹⁵ demonstrated that the plantar plate of the foot is similar in both form and function to the volar plate of the hand. However, those authors noted that the plantar plate is larger and thicker than the volar plate and has a weaker proximal attachment. Deland et al¹⁶ also performed an in-depth anatomical dissection of the plantar plate and outlined several possible functions of the structure. First, the plantar plate merges with the plantar fascia distally and is an integral part of the windlass mechanism. Second, its fibrocartilaginous structure helps to absorb compressive loads acting on the metatarsal head. Finally, its central position and multiple attachments act to stabilize the lesser metatarsophalangeal joint in the plantar direction.

Through mechanical testing, Bhatia et al¹⁷ found the plantar plate to be the main stabilizing force of the metatarsophalangeal joint. The study concluded that the metatarsophalangeal joint collateral ligaments, which have an insertion into the plantar plate, are the second most powerful structures that stabilize the metatarsophalangeal joint. Deland and Sung¹⁸

performed an anatomical dissection of a medial crossover second toe in a cadaveric specimen in an attempt to fully describe the underlying pathologic anatomy found in the condition. The specimen exhibited rupture of the lateral collateral ligaments, shortening of the medial collateral ligaments, attenuation of the plantar plate, and dorsal medial displacement of both the flexor tendons and the plantar plate.

While static stabilization of the metatarsophalangeal joint is primarily the function of the plantar plate, dynamic stabilization is provided by the extrinsic and intrinsic musculature of the foot. It should be noted, however, that the ability of the intrinsic and extrinsic foot musculature to stabilize this joint is dependent largely on the integrity of the plantar plate. When the metatarsophalangeal joint is in a flexed or neutral position, the extensor digitorum longus and extensor digitorum brevis tendons act to dorsiflex the metatarsophalangeal joint through their insertion into the extensor hood apparatus.¹⁹ However, with rupture of the plantar plate, the proximal phalanx assumes a subluxated (dorsal) position, and the extensor tendons are mechanically unable to extend the proximal and distal interphalangeal joints. When the metatarsophalangeal joint is maintained in a subluxated (dorsal) position for a prolonged period, the extensor digitorum longus becomes a deforming force at the metatarsophalangeal joint and results in progressive dorsal subluxation and frank dislocation of the toe.²

The flexor digitorum longus and brevis tendons provide flexion at the proximal and distal interphalangeal joints, but are relatively inefficient flexors of the metatarsophalangeal joint.³ In a weightbearing situation, these muscles act to stabilize the toes against the ground and, in doing so, may cause slight dorsiflexion of the metatarsophalangeal joint.¹⁹ The flexor tendons are therefore unable to aid in stabilization of the dorsally subluxated toe.

Under normal circumstances, the interosseous muscles provide most of the flexion that occurs at the lesser metatarsophalangeal joints.²⁰ However, with dorsal subluxation of the metatarsophalangeal joint, the interosseous tendons migrate dorsal to the axis of the metatarsophalangeal joint and subsequently lose their mechanical ability to provide flexion of the joint.²¹ The lumbrical muscles also play an important role in the dynamic stability of the lesser metatarsophalangeal joint. These muscles arise from the long flexor tendons and insert into the medial aspect of the extensor hood. According to an anatomical and functional study performed by Jarrett et al,²² the interosseous muscles stabilize the interphalangeal joints in the extended position and maintain the

metatarsophalangeal joint in the plantarflexed position during weightbearing. However, like the interosseous muscles, they too lose their ability to provide flexion of the metatarsophalangeal joint when the proximal phalanx is in a subluxated (dorsal) position.³ Thus, in chronic subluxation of the metatarsophalangeal joint, the long and short flexor, interosseous, and lumbrical muscles provide no dynamic restraint to dorsal dislocation of the toe.

The second toe is anatomically unique, having insertions of two dorsal interosseous tendons but no plantar interosseous tendon. The lumbrical tendon has a medial insertion and provides a slight medial pull in the second toe. With chronic inflammation about the metatarsophalangeal joint, progressive dorsal subluxation of the second toe ensues as the plantar plate and collateral ligaments fail in static stabilization of the joint. As a result of the dorsal position of the toe, the normal axes of the intrinsic muscles are lost, rendering them incapable of dynamically stabilizing the joint. The extensor digitorum longus and lumbrical muscles subsequently become a deforming force, contributing to dorsal medial dislocation of the toe.

Further explanation for a dorsal medial dislocation following failure of the plantar plate has been provided by Hatch and Burns,²³ who performed an anatomical dissection of seven cadaveric specimens exhibiting a crossover second-toe deformity. The authors found that four of the seven specimens demonstrated an accessory medial slip of the extensor digitorum brevis tendon to the second toe and believed that this accessory tendon was a contributing factor in the etiology of the crossover second-toe deformity. The current authors have not found this anatomical variant in several cases of predislocation syndrome that have undergone surgical correction.

Anatomically, it is easy to understand why dorsal medial dislocations are most common at the second metatarsophalangeal joint. However, dorsal medial dislocations are also more common than dorsal lateral dislocations at the other lesser metatarsophalangeal joints. The rationale behind this observation is not easily understood, as the other lesser metatarsophalangeal joints have both dorsal and plantar interosseous tendon insertions that directly oppose one another in the transverse plane. Subluxation and dislocation of the lesser toe at the level of the lesser metatarsophalangeal joint, not attributable to the normal progression of the classic hammer toe deformity, are still somewhat of an enigma and continue to challenge physicians who treat foot and ankle problems. The senior author has diagnosed and treated predislocation syndrome involving one or more of the following

digits: second, third, and fourth (Fig. 8). While dorsal subluxation is seen in all of them, the medial or lateral deviation is a peculiar finding not well understood. The authors suggest that an underlying structural metatarsus adductus deformity may influence the type of transverse plane deformity that develops.

Diagnostic Modalities

Several imaging modalities are available to assess instability of the lesser metatarsophalangeal joint, although rarely is extensive or expensive imaging required. When there is clinical evidence of subluxation or dislocation, standard radiography is the most practical diagnostic modality and is essential in ruling out local or systemic pathologies that contribute to lesser metatarsophalangeal joint instability and

dysfunction. Weightbearing lateral or oblique radiographs clearly indicate dorsal subluxation of the proximal phalanx upon the metatarsal head as the condition progresses. Weightbearing anteroposterior radiographs will demonstrate dorsal as well as transverse deviation of the affected toe. The normal clear space of the lesser metatarsophalangeal joint is 2 to 3 mm, and the joint surfaces should be congruent.² When dorsal subluxation or dislocation is present, the clear space is obliterated as the concave base of the proximal phalanx migrates dorsally over the convex metatarsal head. Incongruity of the joint space is noticed as the digit deviates in the sagittal and transverse planes. The anteroposterior radiograph will also demonstrate any abnormal metatarsal length patterns that might contribute to the development and progression of this deformity. Cortical hy-

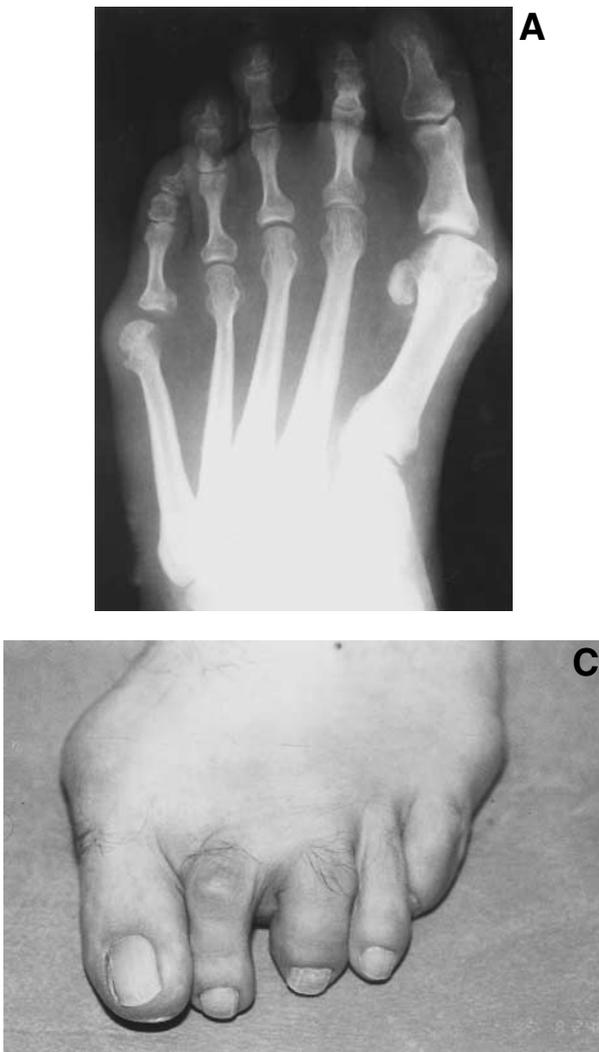


Figure 8. Predislocation syndrome of the third metatarsophalangeal joint. A, Initial radiographic findings were unremarkable; B, a subsequent radiograph demonstrated a complete dislocation of the third metatarsophalangeal joint (arrow); C, note the swelling of the digit and corresponding metatarsophalangeal joint.

pertrophy of the affected metatarsal shaft may be present and is believed to be indicative of abnormal forefoot loading.¹ However, the authors have not found this to be a consistent finding. Finally, a radiographic vertical stress test may also be used to support the clinical findings of sagittal plane instability.

More advanced imaging modalities may be warranted when there is no clear clinical or radiographic evidence of instability. An arthrogram with 0.5 to 1 mL of iodinated contrast material injected dorsally into the metatarsophalangeal joint under fluoroscopy may be used to evaluate the integrity of the metatarsophalangeal joint capsule.²⁴ Rupture of the metatarsophalangeal joint capsule is demonstrated by opacification of the flexor tendon sheath while leakage of the contrast material outside the joint capsule into the intermetatarsal bursa is indicative of collateral ligament rupture.²⁵

Although not typically used, a nuclear medicine three-phase bone scan will show increased tracer uptake at the metatarsophalangeal joint during all three phases.^{6, 11} The first two phases are decidedly more intense than the delayed phase. This pattern strongly suggests a local inflammatory process, rather than an osseous problem. Additionally, a conventional bone scan may be helpful in identifying a stress fracture not identified on conventional radiographs. The pattern of uptake is different from that seen in patients with predislocation syndrome. A stress fracture would show increased uptake in all phases of the bone scan with the greatest uptake in the delayed phase (3 to 6 hours), which demonstrates a linear pattern within the shaft of the affected metatarsal. In contrast, the pattern of uptake in patients with predislocation syndrome is localized to the metatarsophalangeal joint area.

Magnetic resonance imaging (MRI) of the manifestations of predislocation syndrome can be demonstrated on high-field, as well as low-field, magnets. This includes imaging on high-field superconducting extremity images. However, adequate MRI visualization demands a tailored approach. The necessary pulse sequences include sagittal longitudinal relaxation time (sagittal T1), gradient echo transverse relaxation time (gradient echo T2), and short tau inversion recovery (STIR) images and coronal T1 and STIR images, as well as an oblique axial STIR sequence for imaging of the metatarsals and intrinsic muscles of the forefoot.

The selection of pulse sequences is very important. Sagittal images are obtained perpendicular to the long axis of the metatarsals. Coronal images, however, require alignment of the first and second metatarsal heads, with imaging of the lesser metatar-

sophalangeal joints obtained parallel to the second through fifth metatarsal heads. The oblique axial sequence is aligned to the dorsal surface of the foot with a lateral down-sloping orientation. To obtain the scan, merely instruct the technologists to perform a STIR sequence in the plane defined by laying their hand on the dorsum of the forefoot region. This combination of pulse sequences provides a simple yet detailed evaluation of the metatarsophalangeal joints and their associated capsuloligamentous complexes, including the plantar plate.

The plantar plate and its associated structures are best visualized on T1 and gradient echo image sequences.²⁵ In T1-weighted images, the plantar plate is seen as a smooth, low-signal structure running beneath the metatarsal head and proximal phalangeal base. However, the plantar plate may be difficult to distinguish from the thicker, underlying flexor tendons on T1-weighted images. For this reason, it is helpful to obtain gradient echo images in which the plantar plate is slightly hyperintense relative to the flexor tendons.

The MRI findings of plantar plate rupture have been well documented by Yao et al.^{25, 26} A rupture of the plantar plate will demonstrate increased signal intensity within the plate with a loss of continuity.²⁶ The area of rupture will be isointense with synovium and joint fluid and is typically located adjacent to the metatarsal head (Fig. 9). Synovitis of the flexor tendon sheath and distention of the metatarsophalangeal joint capsule are common associated findings in plantar plate rupture and, if present, are readily identified on MRI.

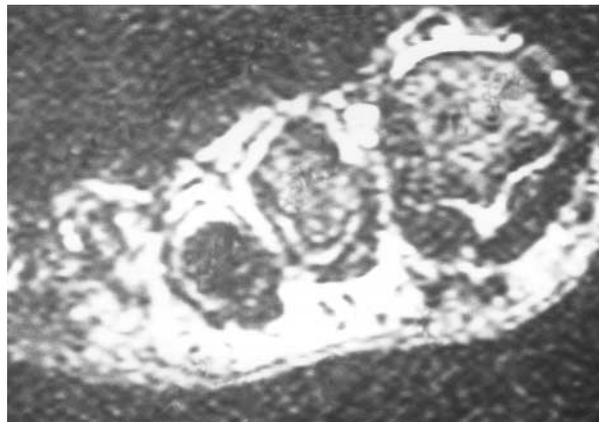


Figure 9. Typical MRI findings of a patient with predislocation syndrome involving the second and third metatarsophalangeal joints.

Conservative Treatment

The goal of conservative treatment for predislocation syndrome is to prevent progression of the deformity and alleviate symptoms. Successful treatment is most often accomplished with a combination of several treatment modalities. Nonsteroidal anti-inflammatory drugs and corticosteroids have been a mainstay for the management of the pain and inflammation associated with this disorder. While a tapered course of oral corticosteroids has been found to be safe and effective, the same cannot be said about repeated intra-articular steroid injections. Dislocation of the toe following repeated intra-articular administration of corticosteroids has been documented in the literature.²⁷ The senior author has witnessed this in several cases where dislocation of the metatarsophalangeal joint was seemingly accentuated by the repeated use of intra-articular steroid injection.

The adverse effects of corticosteroid injection directly into periarticular structures have been recorded in the literature. In one study, a single injection of methylprednisone (4 mg) deposited directly into ligamentous tissues destroyed fibrocytes and decreased the tensile strength of the tissues for as long as 1 year.²⁸ The physician must realize that such an injection may weaken the already compromised plantar plate. However, if intra-articular steroids are deemed necessary, the smallest effective dose of a phosphate salt should be used. Generally accepted guidelines recommend that any given joint be injected a maximum of once every 1 to 3 months and no more than two to three times within a 12-month period.²⁹ A number of factors will influence the frequency of injections; these include the type of steroid, the quantity of the steroid, and the clinical entity being treated. The authors strongly discourage the indiscriminate, repeated use of intra-articular steroids for predislocation syndrome. In the authors' opinion, the use of acetate steroids is rarely, if ever, indicated for the treatment of predislocation syndrome. If intra-articular steroids are employed, splinting of the toe to maintain position and prevent progressive dislocation is strongly recommended.

In addition to pharmacologic therapy, offloading the metatarsophalangeal joint and supporting the toe in a proper position are essential to successful treatment. Taping of the digit into a slightly overcorrected rectus position can prevent pain and progression of the deformity. It is believed that this course of treatment stabilizes the digit enough to allow fibrosis of the periarticular structures to occur. However, there are two main drawbacks to taping of the digit: 1) Taping may take several months before stability and

pain-free ambulation are achieved; 2) a prolonged course of taping may result in edema and possible ulceration of the digit.¹¹ In short, it is simply not practical. Taping is, however, useful in helping to establish the diagnosis of predislocation syndrome at the initial office visit, provided that the metatarsophalangeal joint has undergone only deviation or subluxation, not dislocation. Taping the toe in the correct position often provides immediate relief of the patient's symptoms on weightbearing, confirming the diagnosis of predislocation syndrome.

Splinting may also be used to maintain proper anatomical alignment of the digit. A metatarsal sling pad stabilizes the proximal phalanx in a plantar direction at the metatarsophalangeal joint level by augmenting the function of the plantar plate and preventing hyperextension or dorsal migration of the proximal phalanx. Accommodative padding may also be used to alleviate symptoms at the affected metatarsophalangeal joint. A longitudinal metatarsal pad with a lesser metatarsophalangeal joint cutout can be used to effectively decrease the weightbearing stress on the metatarsal head. A metatarsal pad applied to the foot or used in the shoe is also helpful, but far less effective than the metatarsal sling pad. It will offload the metatarsal but is insufficient in providing direct splinting of the toe in a plantar direction and fails to prevent further dorsal migration and dislocation.

For patients who have received insufficient benefit from taping and padding therapy or are not considered candidates for surgery, shoe modifications may relieve symptoms.^{3-5, 30} An extra-depth shoe to accommodate the digital deformity combined with a rocker-bottom sole with steel shank to decrease propulsive forces on the affected metatarsophalangeal joint may be effective. A viable alternative option for treating this condition is an extra-depth shoe with a metatarsal bar added to the sole.

The authors' typical regimen for the conservative treatment of predislocation syndrome consists of a combination of oral steroids, nonsteroidal anti-inflammatory drugs, and taping or padding. In cases of significant symptomatology associated with moderate to severe inflammation, oral steroids have been very effective. The authors typically use a tapering dose (from 60 to 10 mg in 10-mg increments) of prednisone, administered in twenty-one 10-mg tablets; this regimen is extremely effective clinically and quite cost-effective. This is followed by a course of nonsteroidal anti-inflammatory drug therapy in conjunction with splinting. Additionally, the authors often employ physical therapy and aggressive manipulation to stretch out the dorsally contracted tissues and decrease inflammation.

Crossover taping of the toe in proper position usually provides immediate relief of symptoms in the office (Fig. 10). The patient is permitted to be weight-bearing and ambulate. If the patient is comfortable with this taping, the diagnosis is confirmed. A metatarsal sling pad fabricated from 1/8-inch adhesive foam, moleskin, and tube gauze has been very effective for this condition and is worn for weeks to months until the toe stabilizes or is corrected surgically (Fig. 11). Felt should not be used to fabricate these pads because its bulkiness aggravates plantar discomfort and usually makes it difficult for the pads to fit into normal shoes. Foam does not seem to pose this problem. Prefabricated pads are commercially available for single-, double-, or triple-digit control. Where the toe deviates in more than one plane, it can be splinted to the adjacent toe with a multidigit pad by securing the digital straps to one another.

Varying degrees of success have been reported with conservative treatment of lesser metatarsophalangeal joint instability. Mizel and Michelson⁴ treated patients with a combination of a single intracapsular steroid injection and a laced shoe with a steel shank added to the outer sole. They reported a 70% success rate with this treatment regimen for a 75-month follow-up period. Trepman and Yeo³⁰ also used a single intra-articular steroid injection and a rocker-sole shoe modification to treat lesser metatarsophalangeal joint synovitis. That study included 15 joints in 13 patients with no known history of rheumatologic conditions. At follow-up evaluation, an average of 18 months later, nine joints (60%) were asymptomatic, five joints (33%) were improved, and one joint (7%) had progressed to surgery. Mann and Mizel⁹ treated a group of seven patients with nonsteroidal anti-inflam-



Figure 10. Crossover tape used as a diagnostic tool to evaluate and assess predislocation syndrome.

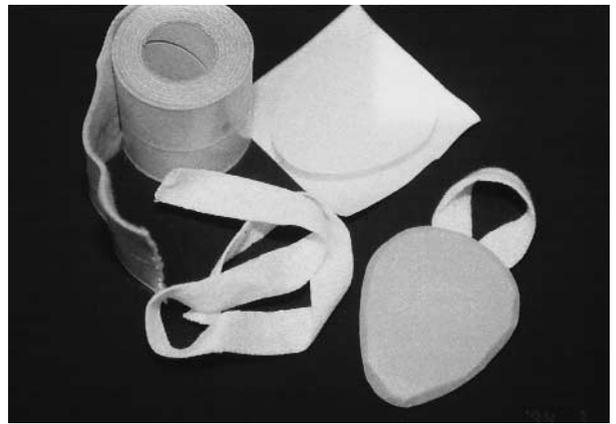


Figure 11. Metatarsal pad to maintain digital position when metatarsophalangeal joint dislocation has not yet occurred is shown along with the materials used to fabricate it. The materials are 1/8-inch foam, moleskin, and tube gauze. Prefabricated pads are readily available.

matory medications and extra-depth shoes with a metatarsal support. Only one patient responded positively to this course of treatment; the remainder progressed to surgical correction of the deformity. Coughlin¹ treated a group of ten athletes with taping for a period of 3 to 6 months combined with a reduction in activity level. Three of the ten patients responded well to this treatment, and six of the remaining seven patients progressed to surgery.

One weakness of these studies is the lack of correlation of the stage of the deformity with the clinical outcome of conservative treatment. In the Coughlin study, all of the patients already had a positive vertical stress test result, and eight of the ten patients had either transverse or sagittal plane deviation at the time of initial presentation. It would seem likely that the number of patients requiring surgical correction would be lower if the disorder was identified and treated prior to obvious or frank subluxation. Nonetheless, the literature bears out that conservative treatment will only prevent progression of the deformity and does not permit realignment of the digit once significant malalignment or instability has occurred.

In the authors' experience, significant alleviation of symptoms can be quickly achieved with conservative treatment; however, the complete resolution of all symptoms is less predictable. Digital splinting and pharmacologic management are used for several months in most cases. Early discontinuation of splinting is likely to result in progressive subluxation and dislocation of the metatarsophalangeal joint. As this occurs, secondary contracture of the extensor digitorum longus tendon develops along with dorsal

contracture of the metatarsophalangeal joint capsule. Once flexibility and reducibility of the deformity are lost, surgical intervention becomes the logical next treatment.

Surgical Management

In light of the frequent failure of conservative treatment in dealing with subluxation/dislocation of the lesser metatarsophalangeal joint, numerous surgical procedures have been advocated to correct the deformity.^{2, 3, 9, 31-37} While there is great divergence in the strategies employed to correct the deformity, the basic goal of all of the procedures is release of periarticular contractures and decompression of the metatarsophalangeal joint to reestablish alignment of the digit. Surgical treatment should focus on restoration of plantar plate function and release of the dorsally contracted structures. The design and extent of surgery will vary with the severity of the deformity and the amount of time that has elapsed since the initial diagnosis.

Several authors have realized the importance of the plantar plate and collateral ligaments in stabilizing the metatarsophalangeal joint and have developed procedures to correct the deformity at this level. Some surgeons have chosen to correct this deformity with direct primary repair of the plantar plate. A plantar incisional approach is employed with direct visualization of the plantar plate. The attenuated or ruptured site is identified, and direct primary surgical repair is performed with or without concomitant arthroplasty or arthrodesis of the proximal interphalangeal joint and release of the dorsal contracted soft tissue.

Ford et al³³ have also advocated primary repair of the plantar plate to correct this deformity. Using a biomechanical testing apparatus, they showed that primary plantar plate repair is as effective as a flexor-to-extensor tendon transfer in stabilizing the metatarsophalangeal joint. However, the study concluded that performing both procedures together was more effective than performing either procedure individually.

Deland et al³² noted the importance of the collateral ligaments in stabilizing the metatarsophalangeal joint and proposed grafting of a partial thickness of the interosseous tendon to reinforce the weakened collateral ligament. Although Deland et al only reported on the procedure as performed in cadaveric specimens, they stated that the benefits of this procedure would include a good range of motion postoperatively, compared with a flexor-to-extensor tendon transfer, and the ability to control the transverse plane alignment of the digits.

Numerous authors have advocated other soft-tissue procedures to correct subluxation or dislocation of the lesser metatarsophalangeal joint. Ruch³¹ has described two different procedures in which the extensor digitorum brevis tendon is transferred to reestablish muscle-tendon balance at the lesser metatarsophalangeal joint. Girdlestone³⁵ is often credited as being one of the first to advocate reduction of the dislocated metatarsophalangeal joint by splitting the long flexor tendon and transferring it to the dorsum of the proximal phalanx. Later, Kuwada and Dockery³⁸ popularized the transfer of the long flexor tendon to the dorsal aspect of the proximal phalanx through a drill hole in the neck of the proximal phalanx. A recent modification of that procedure places the drill hole in the base of the proximal phalanx.³⁹ The benefits of this modification include better reduction of the dislocation owing to a more proximal pull of the flexor tendon and the preservation of the ability to perform either a proximal interphalangeal joint arthroplasty or arthrodesis. The main drawback of all flexor-to-extensor transfer procedures is the decreased dorsal range of motion at the metatarsophalangeal joint that occurs postoperatively. This, however, may also be construed as the main benefit of the procedure, as the goal of treatment is to prevent dorsal migration and dislocation of the toe.

Some authors have used a combination of soft-tissue and osseous procedures to correct the deformity. Daly and Johnson⁴⁰ advocated resection of the bases of the second and third proximal phalanges with subtotal webbing. They believed that subtotal webbing promoted digital stability that was lost as a result of the resection of the bases of the proximal phalanges. Coughlin and Mann¹¹ have recommended relocation of the metatarsophalangeal joint by partial metatarsal head resection and release of the contracted periarticular structures in severe cases of dislocation of the metatarsophalangeal joint. Cracchiolo et al⁴¹ reported on 28 cases in which silicone implant arthroplasty was used to correct second metatarsophalangeal joint dislocation. They reported good results in 88% of patients presenting with multiple forefoot deformities. The authors cited transfer lesions as the most frequent complication of the procedure.

Other osseous procedures that have been used include oblique osteotomies of the head and neck of the metatarsal, with or without fixation. In a comparison of the results of the Weil and Helal osteotomies in correcting dislocation of the lesser metatarsophalangeal joint, Trnka et al³⁶ concluded that the Weil osteotomy was far superior in maintaining the metatarsophalangeal joint in a corrected position and resulted in fewer malunions. They suggest that this is because

the Weil procedure uses stable internal fixation while the Helal procedure allows the metatarsal head to “float” or “seek its own level” after osteotomy. Vandeputte et al⁴² studied the use of the Weil osteotomy for both intractable plantar keratosis and chronically dislocated metatarsophalangeal joints. Of the 59 metatarsophalangeal joints involved in the study, 33 were chronically dislocated. At follow-up at an average of 30 months postoperatively, patients rated the results as excellent or good in 32 of 37 feet (86%). Two symptomatic transfer lesions occurred, and recurrent dislocations occurred in 5 joints. Vandeputte et al concluded that the Weil osteotomy is simple and efficient for the reduction of chronically dislocated lesser metatarsophalangeal joints.

The current authors do not have experience with direct surgical repair of the plantar plate, but have instead chosen to approach this problem by means of various soft-tissue and osseous procedures. A dorsal incisional approach is employed. An arthrodesis of the proximal interphalangeal joint is typically performed. The dorsal soft-tissue release is done in a sequential manner until complete release and relocation of the toe at the metatarsophalangeal joint are achieved. An extensor hood release/recession is followed by a dorsal/medial/lateral metatarsophalangeal joint capsule release. It is not uncommon for a significant amount of synovitis to be present within the joint. Debridement of this inflammatory tissue is performed as needed (Figs. 12 and 13). The toe is stabilized with a Kirschner wire driven across the metatar-



Figure 12. Intraoperative appearance of the second metatarsophalangeal joint following complete relocation of the digit. Note the extensive synovitis within the joint capsule. In addition to soft-tissue release and synovectomy, an arthrodesis of the proximal interphalangeal joint was performed.

sophalangeal joint for 5 to 7 weeks, allowing for soft-tissue adaptation and stabilization of the metatarsophalangeal joint.

If instability of the metatarsophalangeal joint persists following soft-tissue release, a flexor tendon transfer employing the flexor digitorum longus (more commonly) or the flexor digitorum brevis is strongly recommended (Fig. 14). Arthrodesis of the proximal interphalangeal joint alone, although helping to create a rigid beam effect of the toe, may not be sufficient to prevent dorsal subluxation/dislocation of the phalangeal base.

Several types of flexor digitorum longus tendon transfers have been well described in the orthopedic and podiatric literature. Several modifications the current authors employ are worthy of discussion. Regardless of the technique of actual transfer, the authors routinely harvest the tendon at the level of the proximal interphalangeal joint that is undergoing arthrodesis. The plantar tissue is incised at the base of the middle phalanx from the dorsal incision. A secondary plantar incision, although commonly used, is not necessary. The split flexor digitorum brevis tendon is retracted medially and laterally, and the flexor digitorum longus tendon identified. The tendon is retracted into the wound, tagged, and transected at the level of the middle phalangeal base.

The tendon is transferred by means of one of several techniques. The standard technique is to split the tendon and then transfer each of the two halves around the proximal phalanx and suture them together dorsally. Another technique is to suture the end of the tendon distally, split it proximally, and then simply pass it over the proximal phalangeal neck area, creating a “check-rein” type of configuration.



Figure 13. Clinical photograph 6 months following surgery of the patient shown in Figures 2 and 12.



Figure 14. Traditional technique of flexor digitorum longus tendon transfer. Tendon has been harvested at the proximal interphalangeal joint level, split, and brought around the diaphysis of the proximal phalanx. A simultaneous arthrodesis of the proximal interphalangeal joint will further facilitate plantar stabilization of the digit *via* the flexor digitorum longus and flexor digitorum brevis.

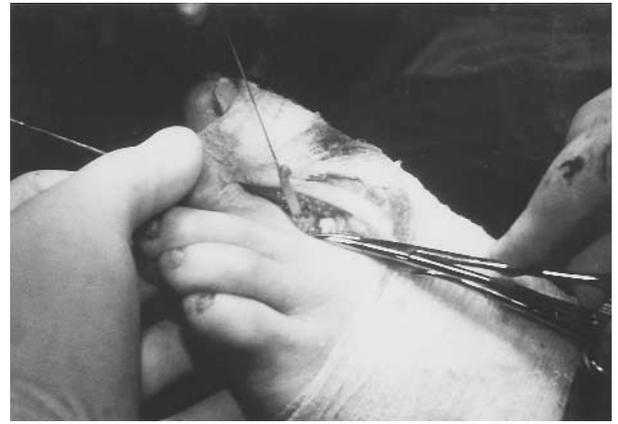


Figure 15. Modified technique of flexor digitorum longus tendon transfer through a drill hole at the base of the proximal phalanx. The tendon is sutured to the dorsal periosteum and extensor digitorum longus tendon. Simultaneous fusion of the proximal interphalangeal joint can be performed. As shown here, the Kirschner wire is driven through the tendon and across the metatarsophalangeal joint if desired.

The authors' current recommendation is to pass the tendon from plantar to dorsal through a drill hole at the proximal metaphyseal–diaphyseal junction and secure it to the dorsal periosteal tissues (Figs. 15 and 16). When the digit is stabilized with a Kirschner wire, the wire is driven through the transferred flexor digitorum longus tendon and across the lesser metatarsophalangeal joint. It is important to impart a physiologic tension to the transferred tendon, as excessive tightness can limit the amount of dorsiflexion

at the metatarsophalangeal joint that is available for normal walking.

In more resistant and recalcitrant cases, an osteotomy of the metatarsal for shortening or angular correction will be necessary. A variety of techniques can be performed depending on the need for, and extent of, shortening *versus* angular correction of the metatarsal segment. A through-and-through oblique osteotomy from dorsal distal to plantar proximal allows for shortening as well as rotation if needed. Small

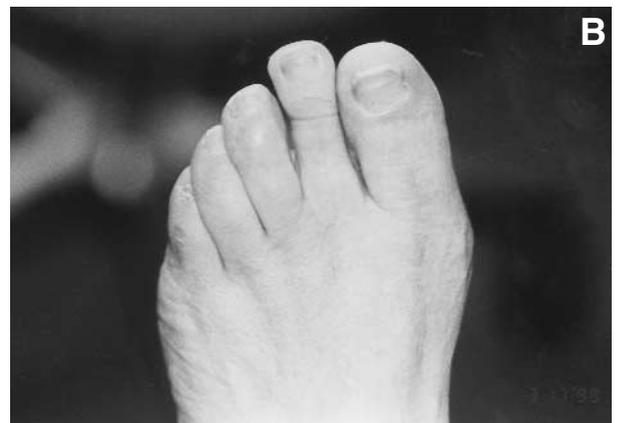
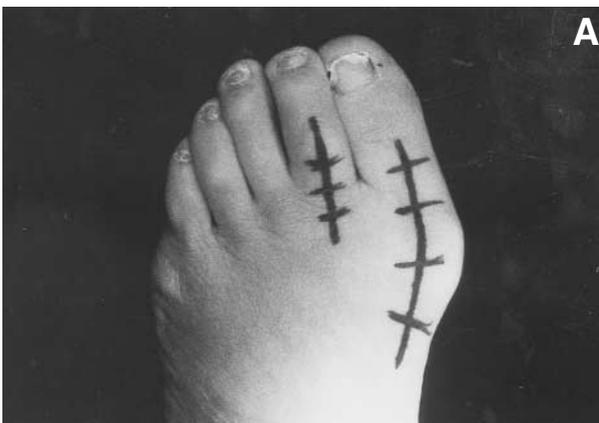


Figure 16. Preoperative (A) and postoperative (B) clinical appearance of the patient in Figure 15 following correction of the hallux abducto valgus deformity as well as arthrodesis and flexor digitorum longus tendon transfer of the second digit.

cortical screws are used to fixate the osteotomy. A shortening Z-osteotomy can also be employed. If only angular change of the metatarsal is needed in the transverse plane, a small wedge osteotomy at the metatarsal base can be very effective; a rotational osteotomy can also be employed. The authors generally reserve metatarsal osteotomy for the more severe and fixed deformity where obvious structural deformity (abnormal length or position) is present (Figs. 17 and 18).

Conclusion

Instability of the lesser metatarsophalangeal joint is becoming well recognized and accepted in podiatric and orthopedic surgery. It is often the sequela of a chronic inflammation resulting from increased and abnormal weightbearing stresses about the lesser metatarsophalangeal joint. The end result of this derangement is attenuation or rupture of the plantar plate, capsule, or collateral ligaments with subsequent subluxation or dislocation of the digit.

This clinical entity has been underrecognized as a cause of lesser metatarsalgia. Although the second digit is most commonly and most profoundly affected (ie, crossover second-toe deformity), the adjacent third and fourth digits can also be affected. Additionally, one or more lesser digits can be simultaneously involved.

The clinical signs and symptoms present on examination can help to stage and chart the evolution of

lesser-toe metatarsophalangeal joint subluxation/dislocation. The treatment of predislocation syndrome is dependent on the stage of the deformity. In early predislocation syndrome, conservative treatment with anti-inflammatory medication, shoe modification, padding, and taping may be successful in preventing progression of the deformity. In long-standing deformity of the lesser metatarsophalangeal joint, surgical intervention is warranted when painful fixed subluxation or dislocation is present and conservative treatment modalities have failed or when prolonged conservative care is not desirable.

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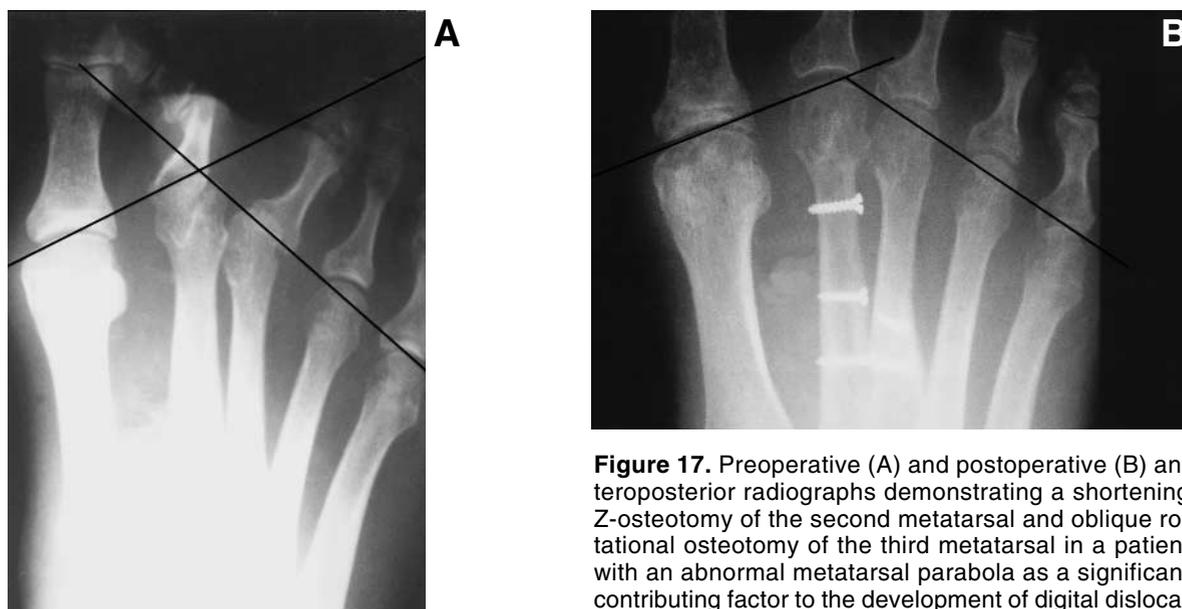


Figure 17. Preoperative (A) and postoperative (B) anteroposterior radiographs demonstrating a shortening Z-osteotomy of the second metatarsal and oblique rotational osteotomy of the third metatarsal in a patient with an abnormal metatarsal parabola as a significant contributing factor to the development of digital dislocations. The lines represent the metatarsal break angle.



Figure 18. Preoperative clinical appearance of the patient shown in Figure 17. Note the complete dislocation of the toes with multiplanar deviation (A) and severe plantar plate inflammation (B). The patient had complete resolution of all symptoms postoperatively.

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