Interdigital Neuritis: Diagnosis and Treatment

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Abstract

Because it has not yet been established whether the condition commonly referred to as Morton's neuroma results from true neuromatous proliferation or from inflammation in the region of the interdigital nerve, the term "interdigital neuritis" is preferred. The authors review the etiology, diagnosis, and management of interdigital neuritis, including whether a plantar or dorsal approach is preferable and whether neurectomy is more efficacious than incision of the transverse metatarsal ligament, with or without neurolysis. The authors recommend that diagnosis be made on the basis of the history and clinical examination, that surgery be performed through a dorsal approach with release of the transverse ligament but without neurectomy, and that revision surgery be performed through a dorsal incision with excision of the nerve 3 cm proximal to the transverse ligament.

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Thomas G. Morton[1] originally described interdigital nerve compression in 1876, suggesting that nerve irritation resulted from compression between the metatarsal heads. Although it is now recognized that this condition is a complex entity involving a myriad of structures in the vicinity of the transverse metatarsal ligament, rather than a neuroma, many continue to use the term "Morton's neuroma." We prefer to use the term "interdigital nerve compression syndrome" or "interdigital neuritis" (IDN).

Pathogenesis

Morton[1] postulated that interdigital nerve irritation was caused by pinching of the nerve between the metatarsal heads, but this theory has proved incorrect, as the nerve lies plantar to the intermetatarsal ligament and metatarsal heads (Fig. 1). In 1940, Betts[2] first recognized that stretching, rather than compression, of the nerve was the cause of neuritis; this finding was confirmed in a pathologic study by Graham and Graham.[3] They demonstrated that the interdigital nerve was distinctly larger in diameter just distal to the intermetatarsal ligament, substantiating earlier work indicating that the edge of the intermetatarsal ligament causes compression of the nerve. They also documented an increased number of blood vessels per fascicle, increased diameter of the nerve, increased perineural width, and increased fascicle diameter just distal to the intermetatarsal ligament. The difference in the number of blood vessels distal and proximal to the intermetatarsal ligament led these investigators to suggest that venous congestion was initially responsible for enlargement of the nerve and that, therefore, enlargement and disruption of the fascicles are secondary changes due to increased venous pressure.

In 1948, Nissen[4] suggested that the pain caused by IDN is ischemic in origin, which was confirmed by histologic examination demonstrating degenerative changes in the arterial wall associated with thrombosis. Nissen subsequently examined nerve specimens and demonstrated a continuous progression of neurovascular changes that occurred with increasing duration of symptoms.[5] Although neuromatous proliferation[6] and inflammatory processes[7] have been proposed as causes of IDN, later studies, such as that by Graham and Graham,[3] disproved these theories. In fact, neither nerve proliferation nor any specific inflammatory process

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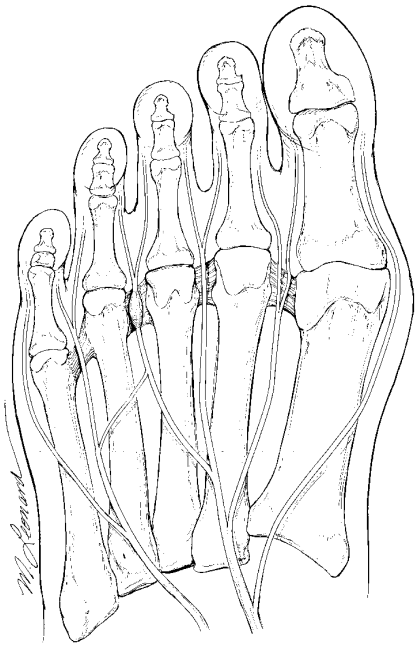

Fig. 1 Normal anatomy of the plantar aspect of the foot.

occurs, and structurally the nerves demonstrate well-formed myelin sheaths with no evidence of Schwann cell proliferation.

Proliferation of fibrous connective tissue in the surrounding stroma and within the plantar digital nerve does occur,[8] however, as does arterial sclerosis with disruption of the internal elastic lamina associated with intimal fibrosis and narrowing of the arterial lumina. Degenerative changes in the arterial wall and disruption of the internal elastic lamina narrow the digital vessel, contributing to local ischemia and further tissue atrophy and thereby causing sensitivity and pain. On the basis of these findings, Ha'Eri et al[8] suggested that repetitive neurovascular trauma occurs in the web spaces, leading to connective-tissue scarring that produces the enlarging mass incorrectly referred to as a neuroma.

The most common histologic findings associated with IDN are perineural fibrosis, neural degeneration, and thickening and hyalinization of the walls of the endoneurial blood vessels. Those of recurrent IDN are completely different, the condition being characterized by the pathologic features of a typical traumatic neuroma—dense fibrous tissue associated with an irregular pattern of nerve tissue.

Anatomic, histologic, and radiologic investigations of the intermetatarsophalangeal bursae in the second and third interspaces have demonstrated that the bursae are distal to the transverse metatarsal ligament and are close to the neurovascular bundle. Inflammation of these bursae may cause secondary fibrosis, which leads to the classic symptoms of IDN.

Bossley and Cairney[9] have suggested that bursitis may occur in the web space, causing inflammatory changes in the nerve. They demonstrated that in the web spaces between the second, third, and fourth intermetatarsals, the bursae lie superior to the transverse metatarsal ligament and project distal to it, but appear closely approximated to the neurovascular bundle. Pathologic specimens demonstrated lymphocytic infiltration with fibrinoid necrosis of the bursal wall.

Bossley and Cairney[9] have also suggested that inflammatory changes in this bursa may account for the pathologic findings in IDN, since injection of corticosteroid into the bursa under radiographic control alleviated symptoms of IDN in their patients, albeit temporarily. Although their results suggest that some of the symptoms of IDN may be secondary to bursitis, this finding has not been corroborated, and the bursal click proposed by Mulder,[10] thought to be pathognomonic of IDN, is only occasionally present.

During the latter part of the stance phase of gait, increased pressure is present under the lesser metatarsal heads, which is transmitted to the intermetatarsal space, located immediately beneath the deep plantar fascia. The anterior edge of the coalesced portion of the plantar fascia irritates and tethers the interdigital nerve, causing the syndrome of pain ultimately recognized as IDN.[2] The high prevalence of this condition in the third web space may be due to the anatomic branching of the medial and lateral plantar nerves in this location. Most neuromas occur in the second and third interspaces, and repetitive trauma—particularly that related to wearing tight shoes and high heels—has been implicated as a major cause of neuritis. In this situation, the more mobile fourth and fifth metatarsals may cause tethering of the digital nerve against the immobile second metatarsal, resulting in inflammation of the nerve.[11]

Although the distribution of IDN has been reported to occur with equal frequency in the second and third interspaces,[12] most authors have identified a much higher percentage of neuromas in the third interspace.[2,6] Because IDN does not occur in the first or fourth web space, the presence of symptoms suggestive of nerve irritation in either location should prompt a search for an alternative source of the pain. Symptomatic IDN may be present concurrently in both the second and third web spaces,[13,14] but an attempt should be made to localize the symptoms to one web space, perhaps with diagnostic lidocaine injection, so that treatment efforts can be focused. For the patient with pain in both the second and third web spaces, further evaluation may be indicated to rule out other causes, such as rheumatoid arthritis. Iden-

tifying the symptomatic web space may be difficult at times, as symptoms may be vague. Diagnosis may be facilitated by use of ultrasonography or magnetic resonance imaging.

In 1940, Betts[2] suggested that the third digital nerve is the largest digital nerve, being formed by branches of both the medial and lateral plantar nerves, and is predisposed to neuroma formation. He also believed that the dual origins of the nerve anchor it about the flexor digitorum brevis, resulting in increased tethering of the nerve over the transverse metatarsal ligament with toe dorsiflexion. With contraction of the flexor muscle, the proximal end of the digital nerve is fixed, restricting the ability of the nerve to slide longitudinally and thereby increasing compression of the nerve by the transverse metatarsal ligament.[2] This theory has been refuted by Levitsky et al,[15] who, in an anatomic study, showed that neuromas can occur in nerves without interneural connection and that a third-web-space nerve formed by dual innervation is no larger than a nerve originating from a single innervation. They also stated that Betts's theories did not explain the substantial incidence of second-web-space neuromas. The investigation by Levitsky et al documented a relative decrease in space in the metatarsal head–transverse ligament region in the second and third web spaces, supporting a mechanical theory for neuroma formation.

Diagnosis

Most patients with symptoms consistent with IDN are middle-aged women (average age, 50 years). Their chief complaint is pain, often associated with burning or tingling of the involved toes. Occasionally, a patient may report only a decrease in sensation. The symptoms are exacerbated by shoe wear, particularly wearing shoes with a tight toe box and those with high heels, which increases the plantar pressure in the forefoot over the metatarsal heads and indirectly leads to further tethering of the nerve as the toes assume a more dorsiflexed or extended position at the metatarsophalangeal joint. Typically, pain is relieved by removing the shoe and massaging the toes or forefoot. Occasionally, the symptoms are atypical, and pain may be localized to only one toe or to the plantar aspect of the forefoot. It is extremely uncommon for diffuse, poorly localized pain associated with paresthesias to be caused by IDN of the forefoot.

Patients with IDN rarely walk with a limp, although occasionally a patient with a painful static forefoot deformity (such as hallux rigidus or hallux valgus) may supinate the forefoot at toe-off and cause irritation of the lateral forefoot, leading to IDN. Generally, the configuration of the arch of the foot is normal, and no study has indicated an association of foot-shape abnormality, either pes planus or pes cavus, with IDN.

Pain in the involved interspace can be reproduced by digital manipulation, with pressure applied just proximal to the metatarsal heads by squeezing the forefoot between the index finger and the thumb (Fig. 2, A). This pain can be exacerbated by simultaneously squeezing the forefoot with one hand and squeezing the web space with two fingers of the opposite hand (Fig. 2, B). Palpation of the involved web space usually causes radiation of the pain toward the involved digit or digits; usually both toes are involved. Squeezing the forefoot and the metatarsal heads together may elicit a palpable click in the involved web space, due to pressure on the intermetatarsal bursa, and may reproduce the patient's symptoms.

It is important to distinguish the pain caused by IDN from that caused by other associated conditions of the forefoot, such as synovitis, bursitis, and metatarsalgia. In metatarsalgia, the pain is localized directly under the involved metatarsal and is usually accompanied by callosity. Synovitis is often confused with neuritis; not infrequently, patients with second metatarsophalangeal joint synovitis are mistakenly treated for neuritis, with excision of a presumed neuroma but no resolution of symptoms.[16] The pain caused by synovitis is located immediately distal to the metatarsal head. Attempting to subluxate the digit dorsally by digital manipulation may tether the nerve and reproduce some symptoms, but the pain associated with this maneuver is more characteristic of synovitis.[17]

Patients with a crossover toe deformity (characterized by dorsomedial deviation of the second toe) may present with symptoms of neuritis in addition to the metatarsophalangeal synovitis. The dorsomedial deviation of the toe probably causes traction on the digital nerve and aggravates tethering of the nerve under the intermetatarsal ligament. Treatment of the toe deformity usually resolves the symptoms of neuritis, and nerve resection should not be required.[18,19]

It is occasionally difficult to distinguish the pain due to bursitis from that due to neuritis, since the locations are similar. If the intermetatarsal bursa enlarges, as occurs in patients with rheumatoid arthritis, the diagnosis is clearer. However, some patients may present with thickening or swelling in

A B

Fig. 2 **A,** Digital manipulation with pressure applied just proximal to the metatarsal heads by squeezing the forefoot between the index finger and the thumb. **B,** Simultaneous compression of the forefoot with one hand and compression of the web space with two fingers of the opposite hand.

the web space associated with symptoms of IDN. Because swelling is not a normal finding in IDN, another source of the pain should be sought, since patients with undiagnosed rheumatoid arthritis may present initially with an enlarged intermetatarsal bursa.[16]

The diagnosis of IDN is made on the basis of the history and the findings from the physical examination. If the diagnosis is in doubt, 1 mL of lidocaine may be injected into the distal web space beneath the intermetatarsal ligament; resolution of the symptoms provides clinical confirmation.

It is unlikely that radiologic studies will be required to confirm the diagnosis. There have been some reports of the successful use of ultrasonography[20] and magnetic resonance imaging[21,22] in the diagnosis of IDN. Positive reports notwithstanding, we believe that these studies are rarely necessary. Magnetic resonance imaging should not be routinely used to diagnose IDN because of the expense involved and because the definitive diagnosis can usually be made on the basis of the physical examination.

High-resolution ultrasonography has been demonstrated to be effective in the diagnosis of IDN. The typical reported sonographic appearance is that of an oval, hypoechoic mass oriented parallel to the long axes of the metatarsals. However, because normal digital nerves cannot be routinely visualized sonographically and because structures less than 5 mm in diameter are difficult to identify,[20] the use of ultrasound as a diagnostic tool is probably limited to cases in which the diagnosis is unclear or the clinical presentation is atypical. Shapiro and Shapiro[23] have reported that ultrasound was useful in diagnosing neuromas in 98% of 50 patients, but that the successful use of ultrasonography was highly operator-dependent. Resch et al[24] evaluated the use of sonography and magnetic resonance imaging in the diagnosis of Morton's neuroma and reported these modalities to be of limited use.

We have found it difficult to differentiate the symptoms of neuritis from those of bursitis and synovitis in patients who have previously undergone forefoot surgery, including resection of an interdigital nerve. Sonographic evaluation has been useful and has confirmed surgical findings in such patients.

Nonsurgical Management

Nonsurgical treatment should always be tried first. Although the results to be obtained with available treatment modalities are unpredictable, approximately 20% of patients will have complete resolution of symptoms.[3] The goal of treatment should be to alleviate pressure on the nerve by decreasing the tension on the intermetatarsal ligament and/or reducing compression of the forefoot. This can be accomplished by increasing the space between the metatarsal heads. Fashionable shoes, particularly those with high heels and a narrow toe box, should

be avoided because they increase lateral compression of the metatarsal heads. A firm crepe sole, which can prevent excessive extension of the metatarsophalangeal joints during toe-off, is ideal but, unfortunately, not always tolerated or accepted by patients.

A metatarsal pad placed directly behind the metatarsal heads will relieve the pressure on the nerve and may increase the space between the metatarsal heads during toe-off. Custom orthoses have met with mixed success in the treatment of IDN.[12] Another recommended treatment is the use of a more rigid arch support.[25]

Rarely does anti-inflammatory medication offer any benefit. Although injection of corticosteroid has been reported to have some clinical benefit,[26] our experience indicates that the effect is often temporary. Repeated steroid injections have not provided long-term relief and should be avoided because of the potential for serious complications, such as atrophy of the plantar skin and systemic side effects.

Surgical Management

General Considerations

Numerous surgical techniques for the treatment of IDN have been reported, including nerve resection from a plantar or dorsal approach and release of the intermetatarsal ligament, with or without neurolysis. Each modality has merits as well as potential drawbacks. Most large series on surgical treatment report a success rate of approximately 80%.[12]

Proponents of a plantar incision for neurectomy maintain that this is a more direct approach, as the nerve is superficial in this location. Although the nerve is not difficult to identify and resect, any complication resulting from the plantar incision can be problematic. Therefore, most clinicians reserve the use of a plantar incision for the treatment of recurrent neuroma formation.

The dorsal approach to neurectomy is technically easier, but adequate nerve resection must be performed. It is important to resect the nerve sufficiently proximally to avoid recurrent neuroma formation. A small incision immediately proximal to the web-space cleft cannot visualize or address the entire nerve and its branches. This concept was highlighted by the anatomic study of Amis et al,[27] which demonstrated the plantarly directed nerve branches from the interdigital nerve. These plantar nerve branches are found immediately proximal to the intermetatarsal ligament, corresponding to the usual sites of neurectomy during IDN surgery (Fig. 3).

These findings are clinically important for two reasons. First, if a neurectomy is performed 1 to 2 cm proximal to the nerve bifurcation, as has been suggested by Betts[2] and others,[12] the plantar nerve branches may prevent retraction of the transected nerve stump proximally into the intrinsic muscle and, therefore, off the weight-bearing surface of the foot. Second, if there is intraoperative injury to one of these plantar branches, each of which represents a small nerve bundle, the result could be a traumatic neuroma with recurrence of symptoms. It is therefore important to identify and resect these nerve branches, which is a procedure that cannot be performed through a limited distal web-space incision. We and other investigators recommend excision of the common digital nerve at least 3 cm proximal to the proximal edge of the transverse metatarsal ligament to reduce the likelihood of tethering or producing a traumatic neuroma.[27]

Release of the Transverse Metatarsal Ligament

As an alternative to neurectomy, some clinicians have proposed division of the intermetatarsal ligament, with or without neurolysis, as an effective treatment for IDN.[28,29] After resection of any interdigital nerve, neural regeneration and neuroma formation may occur. If neuromas form on the plantar aspect of the foot, particularly distally in the region of the metatarsal heads, they are symptomatic.

Gauthier[29] was the first to report on this procedure. He treated 206 patients with 304 nerve lesions by dividing the intermetatarsal ligament and performing epineural

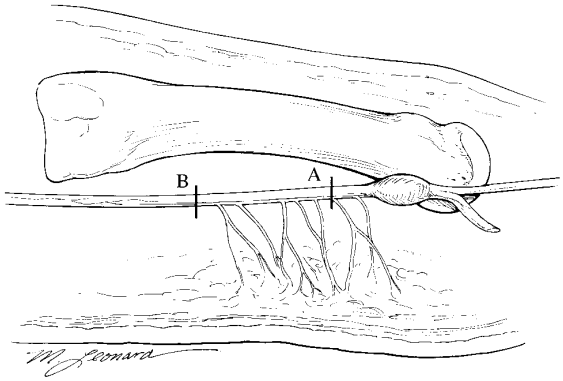

Fig. 3 Lateral view of the plantar branches of the digital nerve. A = previously recommended level of neurectomy (1 cm proximal to ligament); B = currently recommended level of neurectomy (3 cm proximal to ligament).

neurolysis. There was resolution of symptoms in 83% of the patients and improvement but persistence of some pain in 15%. Dellon[28] and Diebold and Delagoutte[14] reported similar results, although they had smaller patient groups. Because these researchers believed that IDN is a nerve entrapment syndrome that should be treated like other nerve entrapments—that is, with release of the offending structures—they released the intermetatarsal ligament without neurectomy, but recommended neurolysis in addition to ligament release. Dellon also recommended opening the epineurium in the region of compression. If good perineural markings were not present and the fascicles were not soft, an interfascicular dissection was performed, and the epineurium was resected. However, neither Dellon nor Diebold and Delagoutte entirely clarified the rationale for performing neurolysis.

Currently, our surgical approach to IDN is ligament release, not neurectomy, without simultaneous neurolysis. The theoretical advantages of this procedure are that the nerve remains intact, no sensory loss occurs, and there is no potential for recurrent and possibly refractory plantar neuroma formation, which may be more difficult to treat than the original problem. Our preliminary results have been good, although long-term follow-up is not yet available for this group of patients. The morbidity of the operation is minimal, and our clinical impression is that patients are able to resume activities more rapidly than after neurectomy. No study has indicated that widening of the forefoot occurs by dividing either one or both of the second- and third-web-space intermetatarsal ligaments. Strapping the forefoot is therefore not necessary during recovery and rehabilitation.

We and other investigators[12] have identified ligamentous tissue that reforms between the metatarsals after reoperation through a dorsal approach for recurrent neuroma. Although this is fibrous scar, it seems to represent some reconstitution of the intermetatarsal ligament. Mann and Reynolds[12] have contended that the presence of this fibrous scar argues against simple division of the intermetatarsal ligament as the sole treatment for IDN. Although this theory is anatomically correct, it is not supported by long-term clinical results,[29] as IDN rarely recurs with this technique.

Neurectomy

Neurectomy remains a simple and popular procedure for the treatment of IDN. It can be performed via a dorsal web-space, plantar longitudinal, or transverse incision.[13,30,31] We recommend a dorsal approach for either primary IDN or recurrent neuroma formation, with wide exposure of the dorsal soft tissues through a 3-cm dorsal longitudinal incision. The superficial soft tissues are dissected, and the interosseous muscles are separated. Insertion of a retractor or a lamina spreader between the metatarsals is helpful to place tension on the intermetatarsal ligament and more fully visualize the soft-tissue structures (Fig. 4). The intermetatarsal ligament is then divided from distal to proximal, using scissors with the tips pointed dorsally to avoid incision of the nerve that lies immediately beneath it. The nerve is then identified and dissected distally to its bifurcation, where it is transected. Traction with slight dorsal elevation on the distal stump of the nerve aids in visualization of the nerve, which is then carefully dissected and divided as proximally as possible. When performing the dissection, it is important to identify and release any branches from the main trunk of the nerve into the plantar tissue, which may be the source of a recurrent neuroma. Patients are able to bear weight on the affected extremity immediately after surgery.

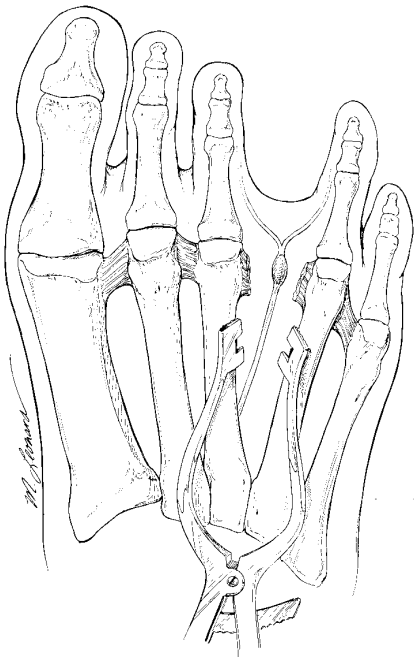

Fig. 4 Resection technique with use of a lamina spreader.

Some clinicians advocate a plantar approach for excision of a primary interdigital neuroma. Betts[2] initially described successful resection of a digital nerve through a plantar incision without complications. This was reinforced by Nissen in 1948.[4] Richardson et al[31] reported a 5% incidence of incisional complications in 172 plantar procedures. Beskin and Baxter[13] reported successful resection of recurrent neuromas through a transverse plantar incision. The authors of these four reports all believed that the plantar approach allows resection of the nerve proximally off the weight-bearing sur-

face without resection of the transverse metatarsal ligament and allows access to both digital nerves if two adjacent web spaces are involved. The most commonly reported complications of plantar incisions are localized scar tenderness, wound drainage, and plantar keratosis.[31]

The plantar incision can be made longitudinally or transversely, depending on the location of symptoms (relevant to one or two web spaces) and the surgeon's personal preference. The longitudinal plantar incision, which is positioned parallel to the elastic fibers of the plantar skin to decrease tension on the wound, provides nearly unlimited access to the digital nerve. Advocates of the transverse plantar incision cite the excellent exposure and the position of the scar distal to the metatarsal heads, which should decrease the incidence of a painful scar.[32]

Although the plantar approach facilitates visualization of the nerve and has been shown to have a low complication rate, incisional complications, when they do occur, can be devastating. A scar on the plantar aspect of the foot may occasionally hypertrophy and become symptomatic. It is rare, however, to experience pain from a symptomatic scar on the dorsum of the foot. Patients may bear weight immediately after surgery with a dorsal incision; in contrast, a plantar approach necessitates a nonweight-bearing period. Most surgeons are more comfortable with a dorsal incision.

Complications of Neurectomy

The cutaneous innervation of the interdigital skin is variable. However, excision of the interdigital nerve is predictably associated with numbness of the web space and, to some extent, of the plantar aspect of the foot just proximal to the level of the web space. Although most patients tolerate the numbness between the toes, loss of sensation that occurs more proximally on the weight-bearing surface of the foot can be quite troublesome. Even after a successful neuroma excision, a patient may still have some difficulty with shoe wear; it is reported that 75% of patients are still limited as to choice of shoe type, particularly with reference to high heels.[12]

Recurrent Neuroma

Persistent pain may be quite problematic after excision of a neuroma, and reported symptoms are similar to, if not worse than, those present before neurectomy. To prevent an amputation neuroma when the interdigital nerve is cut, some clinicians have recommended using silicon caps, metal ligation clamps, or topical corticosteroids or implanting the resected nerve stump into an interosseous muscle.[28,33] However, an anatomic study by Amis et al[27] seems to indicate that adequate proximal dissection of the nerve should decrease the incidence of recurrence. This theory is further supported by Johnson et al,[34] who demonstrated that amputation neuroma and incomplete resection of the initial neuroma result in persistent pain. Therefore, as we have no experience with these supplemental methods, we prefer to avoid the problem of recurrent neuroma by dividing the nerve as far proximally as possible.

In one series, the cause of recurrent symptoms was identified as adhesion of a traumatic neuroma to the plantar aspect of the metatarsal head.[12] However, this finding has not been supported by other studies.[27] Although this situation can occur in some patients, in most, the traumatic neuroma is directly in the web space, tethered to the skin through plantar neural branches, as demonstrated by Amis et al.[27] In some patients, the traumatic neuroma adheres to the undersurface of the intermetatarsal ligament or lies just distal to it; in others, it lies proximal to the transverse metatarsal ligament and adheres to the skin.

Most plantar nerve branches are found on the distal portion of the digital nerve, adjacent to the intermetatarsal ligament, which corresponds to the site at which a neurectomy is commonly performed. If the neurectomy is performed 1 cm proximal to the bifurcation of the nerve, plantar nerve branches may still be present. Therefore, it is unlikely that pulling the nerve distally out of the wound will enable the cut end to retract proximally off the weight-bearing area of the forefoot, since these nerve branches tether the nerve stump distally. Our current recommendation, therefore, is that the nerve should be transected at least 3 cm proximal to the proximal edge of the transverse metatarsal ligament.

Summary

Interdigital nerve compression syndrome results from a constellation of factors in the area of the transverse metatarsal ligament, including hypertrophy of the intermetatarsal bursa, connective tissue, and/or vascular tissue. We currently treat IDN as other compressive neuropathies in the extremities are treated, with release of the offending structures via a dorsal approach, rather than with resection of the digital nerve. Because the long-term results of ligament release alone are not yet available, the standard treatment remains resection of the interdigital nerve. Recurrent neuromas

should be treated with neurectomy through either a plantar or a dorsal approach; the latter may be safer, as it provides full visualization of the nerve. In any neurectomy, the nerve should be transected at least 3 cm proximal to the intermetatarsal ligament to allow retraction of the nerve stump into the intrinsic muscle, preventing recurrent traumatic neuroma formation.

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