The Diagnosis and Management of Morton's Neuroma

A Literature Review

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Abstract: *Morton's neuroma is a common condition mainly affecting middle aged women, and there are many proposed etiological theories involving chronic repetitive trauma, ischemia, entrapment, and intermetatarsal bursitis. Incorrect terminology suggests that the underlying pathological process is a nerve tumor, although histological examination reveals the presence of inflammatory tissue—that is, perineural fibrosis. The common digital nerve and its branches in the third planter webspace are most commonly affected. Diagnosis is usually made through history taking and clinical examination but may be aided by ultrasonography and magnetic resonance imaging. Current nonoperative treatment strategies include shoe-wear modifications, custom made orthoses, and injections of local anesthetic agents, sclerosing agents, and steroids. Operative management options primarily involve either nerve decompression or neurectomy. We have reviewed the published literature to evaluate the outcomes of the available diagnostic modalities and treatment options and present an algorithm for clinical practice.*

Keywords: Morton's neuroma; forefoot; toe; midfoot; peripheral neuropathy; pain management

Introduction

Morton's neuroma (interdigital neuroma, interdigital neuritis, interdigital or Morton's metatarsalgia) is a common and painful condition of the foot. Although there are no data regarding the exact incidence of this condition, it accounts for a significant proportion of the workload of the foot and ankle surgeon. Although there is much debate as to the exact etiology of the condition, it typically causes neuropathic pain in the third webspace. Women are up to 10 times more likely to be affected than men, with the mean age at presentation being around 50 years.[1] The condition was first described in 1835 by Civinini as a fusiform swelling of the common digital nerve of the third intermetatarsal space.[2] Durlacher (Queen Victoria's chiropodist) published a discussion on the management of this condition a decade later, but it was not until 1876 that Thomas Morton, an American orthopaedic surgeon whose name has become synonymous with the condition, published his case series of 15 patients in which he attributed the neuralgia to

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an injury to the fourth metatarsophalangeal joint (MTPJ).[3,4] Commonly mistermed a *neuroma*, numerous studies have histologically demonstrated that the affected tissue is in fact a proliferative fibrosis of perineural tissue instead of a true nerve tumor.[5,6]

Accurate clinical diagnosis can often be difficult in the outpatient setting, and radiological investigations are commonly performed in order to differentiate neuralgia from other causes of forefoot pain—for example, MTPJ degeneration, Freiberg's disease, synovitis, and bursitis. Management strategies must involve obtaining an accurate diagnosis and exploring both conservative and operative measures. There has recently been considerable work into the diagnostic modalities and treatment options available. It is the aim of this article to present the findings of a literature review in order to provide a clear understanding of the pathophysiology, clinical assessment, and radiological and management options of this common and often troublesome condition.

Pathophysiology

The common plantar digital nerves are terminal branches of the medial and lateral plantar nerves and run in the webspace plantar to the intermetatarsal ligaments. Each common digital nerve passes within the plantar aponeurosis and splits into 2 branches supplying the plantar skin of the digits. Smaller branches provide innervation to the adjacent metatarsals, MTPJs, and plantar skin beneath the metatarsals.[7] Usually, the third common digital nerve receives a large communicating branch from the lateral plantar nerve, which passes deep to the deep transverse metatarsal ligament (DTML) at the third webspace, explaining why this is a common location for the lesion. A diagram has been provided in Figure 1 to illustrate this anatomy.

Currently 4 main etiological theories exist and have been well summarized by Hassouna and Singh.[8] The chronic trauma theory suggests that repetitive trauma occurs to the forefoot and plantar intermetatarsal structures, including the communicating branch in the third webspace. This may be aggravated during ambulation in which dorsiflexion of the toes and contraction of the flexor digitorum brevis stretches the common digital nerve, causing a traction injury. Nissen[9] proposed an ischemic theory after the microscopic and histological examination of 27 resected lesions and associated plantar digital arteries. He observed that there were severe degenerative changes to the artery, including disruption of the arterial wall, thrombosis, and incomplete recanalization. However, other studies have revealed similar arterial appearances in controls.[10,11] The intermetatarsal bursitis theory suggests that the presence of a bursa in the second and third webspaces may be a contributing factor because it lies close to the common digital neurovascular bundle. An inflammatory bursitis may cause subsequent fibrosis of the adjacent nerve.[12] An entrapment theory states that during ambulation, the common digital nerve becomes trapped by the anterior edge of the DTML, leading to neuralgia. Gauthier initially proposed this theory and recommended surgical release of the anterior edge of the DTML without resection of the lesion.[13] Furthermore, a separate pronation theory proposes that in an over-pronated foot, the third intermetatarsal space is reduced, allowing for symptomatic neural compression.[14] It is important to bear in mind that these theories represent processes that may be occurring concurrently.

Figure 1.
Anatomy of Morton's Neuroma.

Histologically, numerous sources have examined resected neural tissue and demonstrated the presence of perineural and epineural fibrosis, degenerative vascular changes, axonal demyelination, fibrinoid degeneration, arrested axonal nerve endings with spontaneous impulse generation, and an increase in sympathetic nerve fibers.[15,16] However, a histological comparison revealed that these changes, with the exception of demyelination, were commonly identified in both symptomatic and asymptomatic patients.[17]

Clinical Assessment

Classically, a burning pain is localized to the plantar aspect of the third webspace in between the third and fourth metatarsal heads, although it can occur less commonly in the second and, rarely, the first and fourth webspaces.[18] Occasionally, this pain can radiate to the toes and be associated with paresthesia. Pain is aggravated by walking in shoes with a narrow toe box or high heels and may be relieved by changing footwear and massaging.[19]

To help provide an accurate clinical assessment, a full foot and ankle examination should be performed paying particular attention to footwear, gait, over-pronation, soft-tissue changes, and sensory disturbances. Certain provocative tests can also be performed, including the webspace tenderness test and the metatarsal approximation or foot squeeze test, both of which are positive if the patient experiences pain. Also, the plantar percussion test (analogous to Tinnel's test) can be performed over the affected webspace producing pain or paresthesia when positive. Perhaps, the most well-known test is Mulder's sign, which is described as a palpable click with concurrent pain when "the patient's foot is clasped around the metatarsal heads with the fingers of the left hand while the thumb of the right hand exerts firm pressure on the sole of the foot at the site of the suspected neuroma."[20]

Cloke and Greiss described the digital nerve stretch test.[21] Bilaterally, the lesser toes on either side of the affected webspace are passively fully extended, with the ankles held in dorsiflexion and both feet on the examiner's knees. Pain or discomfort in the webspace of the affected foot indicates a positive result. In their case series of 22 patients, comparison was made between preoperative clinical testing and postoperative histological diagnosis. They found that this sign showed 100% sensitivity with a 95% positive predictive value. However, it was also positive in 1 patient with an epidermal cyst. They also noted that Mulder's sign showed 95% sensitivity, 100% specificity, and positive predictive value with a false negative rate of 5%. Both the webspace tenderness and metatarsal approximation tests had 100% false-positive rates.

In a larger case series of 76 cases of patients undergoing neurectomy, a comparison of 4 clinical tests was made with a control group.[22] Postoperative positive histological examination was confirmed in 99% of feet in the study group. Positive foot squeeze test (analogous to Mulder's sign) results were similar in both groups, but the combination of positive foot squeeze and webspace tenderness tests were significantly more common in the study group. There was no difference in toe tip sensation deficit between the groups, but in association with any other positive test, a positive result was significantly more common in the study group. The plantar percussion test was the least sensitive, being positive in only 62% of the study group. Although there was no single pathognomic test, the combination of more than 1 test being positive was significantly associated with a symptomatic lesion.

Radiological Investigation

Plain radiographs are useful to differentiate between other causes of webspace pain such as osteoarthritis, Freiberg's disease, and stress fracture. It may show splaying of the metatarsals or a small soft-tissue shadow corresponding to the lesion, but this is not diagnostic.[23] Currently, the most commonly used investigations are ultrasonography and magnetic resonance imaging (MRI). However, in a recent comparison between clinical assessment with both ultrasonography and MRI, Pastides et al[24] found that clinical assessment was most sensitive and recommended that radiological investigations be reserved for unconvincing cases, suspected multiple lesions, or multiple webspace involvement.

Ultrasound scans (USSs) are convenient and inexpensive, are able to demonstrate an ovoid hypoechoic mass parallel to the long axis of the metatarsal, and are more accurate when the lesion measures more than 5 mm. A biconcave appearance has also been suggested to be the result of compression by adjacent structures.[25] However, whereas some investigators report a sensitivity of 85% to 100%, others have questioned its value, raising concerns over an inability to separate the lesion from associated mass-like mucoid degeneration in adjacent loose connective tissue, potentially incurring high false-positive rates.[26-28] Furthermore, in an observational study of 48 asymptomatic feet, 54% were found to have sonographic nerve thickenings, indicating that clinical correlation is essential in guiding treatment for symptomatic lesions.[29] As with all forms of ultrasonography, the technique and interpretation of the results are operator dependent.

MRI examination reveals a mass with low signal intensity and is able to distinguish it from other soft-tissue masses with a high signal intensity—for example, bursae, schwannomas, and neoplasms.[30] Limited MRI examination using axial T1-weighted images provides diagnostic accuracy with low false-negative and false-positive rates.[31] However, in a recent comparative study, the reported sensitivity for MRI in diagnosing a symptomatic lesion was only 88% compared with USS investigation, which had a sensitivity of 96%.[32] MRI has also demonstrated the presence of a lesion in up to one-third of asymptomatic patients.[33] Although both USS and MRI can help provide a diagnosis in difficult cases, they are less sensitive than clinical examination and can predict neither symptom severity nor outcome.[34]

Nonoperative Management

There is an extensive range of nonoperative options available in treating symptomatic lesions, and these are aimed at reducing pressure, inflammation, and nerve irritation. Modifications to footwear have been shown to improve symptoms in up to 41% of patients but give lower satisfaction rates when compared with steroid injections.[35,36] Pronation and supination orthoses have been shown to be ineffectual in relieving pain.[37]

Radiofrequency ablation (RFA) was first described in the treatment of Morton's neuroma by Finney et al in 1989.[38] Genon et al[39] studied 37 patients treated with RFA who had all previously failed conservative therapy and found that only 18.4% reported complete symptom relief. Most recently, Moore et al[40] attempted RFA on 29 patients, with 83% reporting complete pain relief at 1 month. However, in both these studies, patients were given a corticosteroid injection during the procedure, which represents an important confounding variable because the reported results cannot be attributed to RFA alone. Extracorporeal shock wave therapy can be performed in an outpatient setting, and in a randomized, placebo-controlled double-blinded trial of 25 feet, Fridman et al[41] found that compared with the control group, there was a significant reduction in visual analogue pain scores up to 12 weeks. However, this trial did not use a power calculation to determine an adequate sample size; only involved small numbers of patients, leading to the potential of a type II error; and used only subjective outcome measures during a short follow-up time period.

Localized injections are widely used and consist of the administration of local anesthetic agents, alcohol, and steroids into the affected webspace. Technical success may be improved through the use of USS or electostimulatory devices. Local anesthetic injections have the advantage of being able to provide an immediate diagnostic tool by blocking the affected nerve. However, the effects are short-lived and do not improve the results of potential surgery.[42] Chemical neurolysis with alcohol is an effective and safe treatment strategy. Complete symptom resolution has been reported in up to 89% of patients, with USS-proven reduction in lesion size at 6 months after the last injection.[43,44] However, multiple treatments are often required, and complications include periprocedural pain (16.8%), allergic reaction (1.1%), and failure, with up to 20% progressing to surgery.[45] What is most commonly used is the local administration of steroid either alone or in combination with a local anesthetic agent. A dorsal approach should be used because there is a risk of plantar fat pad atrophy with a plantar approach, which may cause pain and gait disturbance.[46] Patients must be adequately counseled that multiple injections may be required, with results diminishing over time. There have been varied reports in terms of success, and these are presented in Table 1.[36,47-51]

Operative Management

Whereas many surgeons advocate surgical intervention when conservative measures fail to relieve symptoms, some recommend operative management as first-line treatment. In a questionnaire-based study of 65 cases, Gaynor et al[52] found no success with shoe modifications, limited benefit from injection therapies, and a far greater chance of a successful outcome with surgical therapy as compared with conservative measures. In those with symptoms of less than 6 months' duration, 38% were successfully treated with initial conservative measures, whereas 62% had success with surgery. In those with symptoms lasting longer than 6 months, only 17% were successfully treated with conservative measures, whereas 83% had a successful surgical outcome. Historically, the main surgical options have included nerve decompression (with neurolysis or translocation of the affected interdigital nerve) and neurectomy (complete excision of the affected part of the interdigital nerve).

The most commonly used surgical approaches to the interdigital nerve are through dorsal and plantar longitudinal incisions, although transverse plantar, web-splitting, and Y-incision approaches have also been described. The plantar incision provides direct access to the lesion but can be associated with painful scar hypertrophy because it is located directly over the weight-bearing area of the forefoot. The dorsal approach involves dividing the intermetatarsal ligament, and although it can avoid a painful weight-bearing scar, nerve branches that are oriented in a plantarward direction can be missed, potentially increasing the risk of recurrence.[53] There are only a few studies that directly compare the outcomes of these 2 approaches. In the only prospective study, Nashi et al[54] found that the dorsal approach was associated with earlier weight bearing (16 days vs 23 days, mean) and return to work (22 days vs 37 days, mean) in a series of 52 patients with an average of 3.1 years of follow-up. Painful scars were seen more commonly in the plantar group (5 vs 2), and there was no difference in the rate of recurrence (1 in each group). In support of these findings, Faraj and Hosur[55] retrospectively examined 42 feet, with a mean follow-up of 18 months and found that the time to weight bearing and return to work, driving, and recreational activities were shorter by at least 1 week in the dorsal group. However, in a larger study of 125 patients with a minimum follow-up of 2 years, Akermark et al[56] compared the results of 2 surgeons, each using a different approach (plantar vs dorsal) and found no difference in terms of clinical outcome and patient satisfaction. There were also significantly more cases of long-term sensory disturbance (73% vs 53%); mean postoperative sick-leave weeks (3.7 vs 2.2); postoperative treatments, for example, NSAIDS and corticosteroid injections (27% vs 3%); and complications (17% vs 5%) in the dorsal group compared with the plantar group.

The technique of nerve decompression was first described by Gauthier[13] in 1979 and was based on his entrapment theory. He recommended this as an alternative to neurectomy to avoid complications such as loss of sensation, sweat disturbance, and stump neuroma. Endoscopic decompression of the intermetatarsal nerve was initially described in a cadaveric study by Barrett and Pignetti,[57] with theoretical advantages of smaller incisions, more rapid recovery, less postoperative pain and swelling, and a lower rate of hematoma and infection. Shapiro[58] later reported on a simpler technique using a single portal and highlighted the need for adequate visualization of the intermetatarsal ligament prior to release in order to avoid inadvertently sectioning the lumbrical tendon. The results of surgical decompression are summarized in Table 2.[13,58-64]

Open neurectomy involves resection of the pathological part of the intermetatarsal nerve and is the most common surgical treatment in patients with persistent symptoms, although many surgeons advocate this as first-line treatment. Patients must be warned about the risks of infection, numbness, painful stump neuroma, chronic pain, and recurrence. Excision of the lesion can be performed through either dorsal or plantar approaches, with a typical 3-cm incision placed over the affected intermetatarsal space. A self-retaining retractor is used to improve visualization and place the soft tissues under tension. Digital pressure can aid in delivering the lesion into the wound. After identifying the bifurcation of

Table 1.

Results of Steroid Injection Therapy.

Study	Level of Evidence	Agent	Local Anesthetic	USS Guidance	Number of Cases	Follow-up (Mean)	Number of Injections (Mean)	Complete Resolution of Symptoms	Progression to Surgery
Greenfield et al[47] (1984)	IV	Prednisolone, betamethasone, triamcinolone	Xylocaine	No	65	3.8 Years	3.8	28%	16.9%
Rasmussen et al[48] (1996)	IV	Betamethasone	Bupivacaine	No	51	4 Years	1	53%	47%
Saygi et al[36] (2005)	II	Prednisolone	Prilocaine	No	34	1 Years	3	82.4%	NR
Hassouna et al[49] (2007)	IV	Triamcinolone	Bupivacaine	Yes	39	11.4 Months	1	28%	7.7%
Markovic et al[50] (2008)	IV	Betamethasone	Lignocaine	Yes	39	9 Months	1	28%	31%
Makki et al[51] (2012)	III	Prednisolone	Lignocaine	Yes	39	12 Months	1	Improvement in pain, function, and satisfaction at 6 weeks but at 6 months only in lesions <5 mm	15%

Abbreviations: USS, ultrasound scan; NR, not reported.

Table 2.

Results of Surgical Decompression.

Study	Level of Evidence	Number of Cases	Follow-ups (Months, Mean)	Approach	Neurolysis	Translocation	Results	Complications
Gauthier[13] (1979)	IV	304	21	Dorsal	Yes	No	85% Complete resolution	NR
Dellon[59] (1992)	IV	11	33	Dorsal	Yes	No	80% Complete resolution; all return to employment and athletic activity	NR
Diebold et al[60] (1996)	IV	40	60	Dorsal	Yes	No	92.5% Excellent result, 87.5% normal toe sensation	NR
Okafor et al[61] (1997)	IV	35	21.4	Dorsal and plantar	Yes	Yes	48% Complete resolution, 37% mild pain; 97% reported good outcome	NR
Vito and Talarico[62] (2003)	IV	82	120	Dorsal	No	Yes	95% Complete resolution	4.8% Residual pain
Villas et al[63] (2008)	III	23	24	Dorsal	Yes	No	95.7% Complete resolution	8.7% Complex regional pain syndrome
Shapiro[58] (2004)	IV	40	NR	Endoscopic	No	No	92.5% Excellent results	7.5% Required open neurectomy
Barrett et al[64] (2012)	IV	193	4	Endoscopic	No	No	92% Good or fair outcome, 7.7% poor outcome	3.6% Required open neurectomy

the common digital nerve, the affected area is carefully inspected and the nerve transected 3 cm proximal to the DTML to allow retraction of the nerve in order to prevent a painful stump neuroma.[53] Adjacent capsular nerve branches must be cut because they may prevent proximal migration of the nerve stump.[65] Alternatively, the proximal end of the nerve can be transposed and implanted into an intrinsic muscle in the arch of the foot—for example, flexor digitorum brevis. The lesion is then fully excised by further transection 1 cm distal to the bifurcation with cauterization or ligation of the nerve endings. Following hemostasis, the wound is closed, and bulky compressive dressings are applied. If a dorsal approach is used, patients can bear weight immediately; otherwise, up to a 2-week period of protected heel weight bearing will be required to allow the plantar wound to heal uneventfully. The specimen is then sent for histological examination to confirm the presence of perineural fibrosis, which provides a diagnostic advantage over decompression. A summary of the results of neurectomy are presented in Table 3.[66-71]

Discussion

Despite being such a frequently encountered condition, controversies remain with regard to the causative mechanisms involved. Although it is clear from histological studies of symptomatic patients that the affected digital nerve undergoes perineural fibrosis rather than a tumor-like enlargement, debates continues as to the precipitating factors involved. The proposed theories are important because they underline the concepts behind management. Chronic, repetitive trauma secondary to altered gait patterns, bursitis, or mechanical entrapment by the DTML appears to be a common theme and is likely to be the major contributing factor to the inflammatory processes involved. Also, anatomical considerations such as the presence of a communicating branch in the third webspace can help explain the high incidence of lesions in this location. The clinical presentation is better understood, and although a burning pain in the third webspace of a middle-aged female patient classically lends itself to the diagnosis, other common causes of webspace pain must be considered—for example, MTPJ osteoarthritis. A variety of specific clinical tests have been devised to reduce the number of false positives, and these have been reviewed in comparative studies.[20-22] It has been shown that no single test can be pathognomic, but in combination, 2 or more positive results are highly sensitive and significantly associated with a positive histological result. The role of radiological investigation invites further debate but has been shown to be less effective than clinical examination by some authors, who propose that USS and MRI should be reserved for those with unconvincing signs and symptoms or multiple lesions.[24,34] To further complicate the issue, asymptomatic patients have been shown to have the radiographic features associated with symptomatic patients using both imaging modalities.[29,33] In practice, the result of radiological investigations must be correlated with clinical findings and in unclear symptomatic cases, excision biopsy may be the only way of obtaining a definitive diagnosis.

Concerning the results of nonoperative management, the reviewed articles were of limited quality (levels of scientific evidence mainly III or IV), with relatively low numbers of patients. A questionnaire-based study performed by Gaynor et al[52] presented results in favor of surgical management, particularly in those with symptoms of greater than 6 months' duration. However, this interpretation may have been influenced by systematic error in the way of recall bias because of its retrospective nature in obtaining data. The most commonly reported method of nonoperative treatment is the use of steroid injection plus local anesthetic therapy.[13,58-64] It should be emphasized to patients that although a satisfactory outcome can be achieved in most (up to 82.4%), multiple injections are usually required, and nearly half will eventually require surgery as a result of persistent symptoms.[36,48]

Regarding operative measures, the reviewed articles were of low levels of scientific evidence (mainly III or IV) involving uncontrolled or poorly controlled case series. This may help explain the large disparities between their results. Direct comparison between the studies was not possible because of the variety of different outcome measures used. It was also noted that complications were incompletely reported, particularly in the articles concerning decompression. Most commonly reported were the results of surgical neurectomy.[66-71] Following this procedure, complete pain relief was seen in up to 68%, with better results reported when used in combination with transposition of the transected proximal nerve stump.[66] Patient satisfaction rates were generally reported as being higher, but this may reflect the variety of unvalidated outcomes measures used to determine this. Although decompression appears to have given superior results (up to 95% complete resolution of symptoms) and fewer complications associated with sensory disturbance, up to 14.5% had mild persistent pain but with only 4.8% requiring neurectomy.[13,59,63] Endoscopic decompression uses smaller incisions and has a more rapid recovery but is a more demanding procedure requiring specialist training and equipment. Well-designed randomized controlled trials would need to be conducted to accurately determine the benefit of decompression over neurectomy.

Another area of controversy is the approach used when performing surgery. The dorsal approach has been more commonly reported and can prevent painful scars on the weight-bearing area of the foot, but because of division of the DTML, splaying of the forefoot can be a problem. Also, there is higher theoretical risk of recurrence as a result of inadvertently missing plantarward-directed nerve branches during neurectomy. The plantar approach affords improved visualization but risks scar tenderness in up to one-third of

Table 3.

Results of Primary Neurectomy.

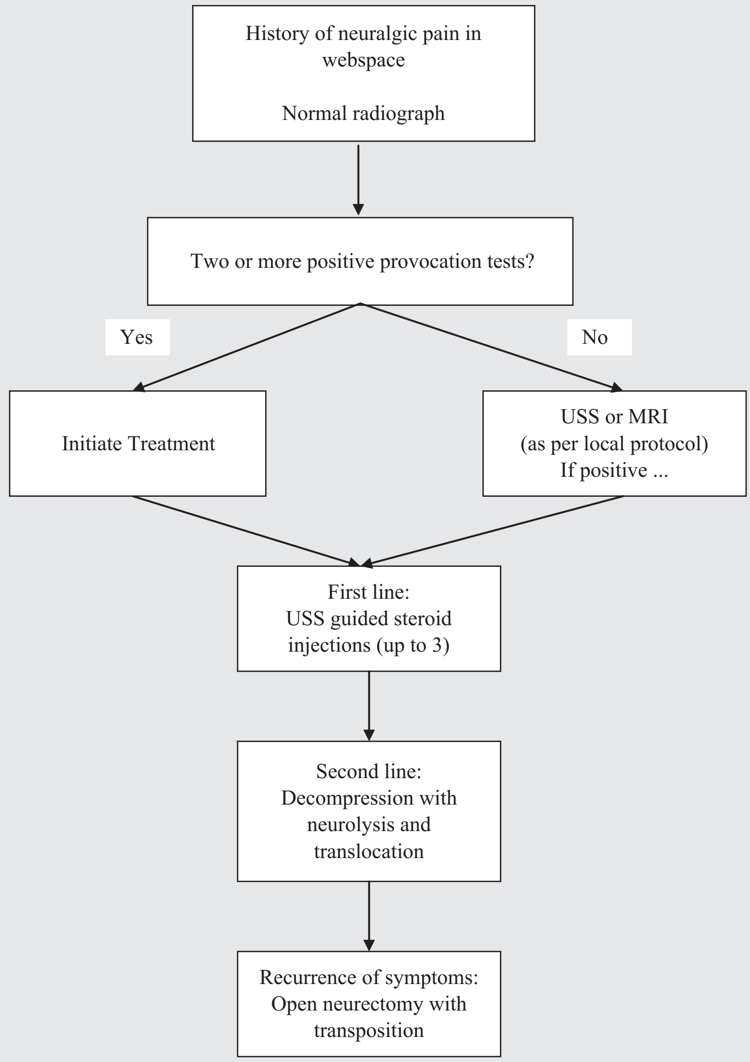
Study	Level of Evidence	Number of Cases	Follow-up (Months, Mean)	Approach	Transposition	Results	Complications
Colgrove et al[66] (2000)	II	45	48	?	73%	>50% Reduction in pain: transposition group, 100%; resection group, 86%	Wound infection, 2.2%
Coughlin and Pinsonneault[67] (2001)	IV	71	69	Dorsal	No	Satisfied, 85%; complete pain relief, 65%; shoe-wear restrictions, 70%; activity restrictions, 38%	Paresthesia, 51%; peripheral neuropathy, 2.8%; wound infection, 1.4%; reflex sympathetic dystrophy, 1.4%; MTPJ instability, 1.4%; plantar keratosis, 15.4%
Akermark et al[68] (2008)	IV	59	24	Plantar	No	>50% Reduction in pain, 93%; satisfied, 86%	Paresthesia, 54%; scar tenderness, 32%
Valente et al[69] (2008)	IV	25	45	Dorsal	No	Complete pain relief, 68%; shoe-wear restrictions, 36%; activity restrictions, 28%	Paresthesia, 52%
Pace et al[70] (2010)	IV	82	55	Dorsal	No	Completely satisfied, 52.5%; excellent or very good outcome, 81%	Wound infection, 9.7%; scar hypersensitivity, 6%; keloid scar, 4.7%; recurrence, 9.7%
Lee et al[71] (2011)	IV	13	126	Dorsal	No	All improved; AOFAS and VAS scores (not statistically significant); shoe-wear restrictions, 33%; satisfied, 61.4%	Paresthesia, 81.8%

patients, although this can be minimized by careful placing of the incision to avoid weight-bearing areas.[68] The reviewed studies gave contrasting results but were of a retrospective nature or poorly controlled.[54-56]

The recurrence of symptoms presents a challenging problem and can be the result of an incorrect initial diagnosis, failure of nonoperative interventions, inadequate resection, or occurrence of a stump neuroma. Young and Lindsey[72] proposed that stump neuromas are primarily found on the plantar surface proximal to the metatarsal condyles and medial to the affected intermetatarsal space. To prevent recurrence following neurectomy, the lesion should be resected 3 cm proximal to the DTML or transposed into surrounding muscle tissue. Transection 1 cm distal to the bifurcation of the common digital nerve with cauterization or ligation of the nerve endings can also prevent formation of a stump neuroma. Wolfort and Dellon[73] presented the results of transposition of the proximal end of the transected nerve into adductor hallucis brevis in a series of 17 recurrent interdigital neuromas. At a mean follow-up of 33.8 months, all patients reported a good or excellent outcome, with no complications seen. This highlights the need for adequate patient counseling because even following neurectomy, recurrence is reported in up to 1 in 10.[72]

Figure 2.

Algorithm for the Management of Morton's Neuroma.



Abbreviation: USS, ultrasound scan.

Conclusion

Morton's neuroma is a common yet complicated pathological process resulting in perineural fibrosis of the common digital nerve branches mainly affecting the third planter webspace of middle-aged females. Although, many theories exist as to the exact etiology, chronic repetitive trauma appears to play an important role. Clinical evaluation using simple bedside tests should form the diagnosis in the majority of cases, with only a small proportion requiring further radiological assessment. A review of the literature reveals a lack of high-quality evidence-based research but highlights some successful treatment options, including local steroid injection, nerve decompression, and neurectomy. Transposition of the proximal nerve stump during neurectomy improves outcome in terms of pain and can prevent the formation of stump neuroma. Areas of future research should include well-designed randomized controlled trials comparing operative with nonoperative management, surgical approaches, and decompression with neurectomy. A proposed algorithm based on current evidence is presented in Figure 2. FAS

References

1. Thomson CE, Gibson JN, Martin D. Interventions for the treatment of Morton's neuroma. *Cochrane Database Syst Rev*. 2004;(3):CD003118.
2. Civinini F. Su di un gangliare rigonfiamento della piñata del piede. *Mem Chir Arcispedale di Pistoia*. 1835.
3. Durlacher L. *A Treatise on Corns, Bunions, the Disease of Nails, and the General*

Management of the Feet. London, UK: Simpkin, Marshall; 1845.

4. Morton TG. A peculiar and painful affection of the fourth metatarso-phalangeal articulation. *Am J Med Sci*. 1876;71:37-39.
5. Levitsky KA, Alman BA, Jevsevar DS, Morehead J. Digital nerves of the foot: anatomic variations and implications regarding the pathogenesis of interdigital neuroma. *Foot Ankle*. 1993;14:208-214.
6. Morscher E, Ulrich J, Dick W. Morton's intermetatarsal neuroma: morphology and histological substrate. *Foot Ankle Int*. 2000;21:558-562.
7. Young G, Lindsey J. Etiology of symptomatic recurrent interdigital neuromas. *J Am Podiatr Med Assoc*. 1993;83:255-258.
8. Hassouna H, Singh D. Morton's metatarsalgia: pathogenesis, aetiology and current management. *Acta Orthop Belg*. 2005;71:646-655.
9. Nissen KI. Plantar digital neuritis (Morton's metatarsalgia). *J Bone Joint Surg Br*. 1948;30-B:84.
10. Meachim G, Abberton MJ. Histological findings in Morton's metatarsalgia. *J Pathol*. 1970;103:209-217.
11. Ringertz N, Unander-Scharin M. Morton's disease: a clinical and patho-anatomical study. *Acta Orthop Scand*. 1950;19:327.
12. Bossley CJ, Cairney PC. The intermetatarsophalangeal bursa: its significance in Morton's metatarsalgia. *J Bone Joint Surg Br*. 1980;62-B:184-187.
13. Gauthier G. Thomas Morton's disease: a nerve entrapment syndrome. A new surgical technique. *Clin Orthop*. 1979;142:90-92.
14. Root ML, Orien WP, Weed JH. *Normal and Abnormal Function of the Foot, Clinical Biomechanics*. Vol 2. Los Angeles, CA: Clinical Biomechanics; 1977.
15. Betts L. Morton's metatarsalgia neuritis of the fourth digital nerve. *Med J Aust*. 1940;1:514.
16. Kay D, Bennett GL. Morton's neuroma. *Foot Ankle Clin*. 2003;8:49-59.
17. Bourke G, Owen J, Machet D. Histological comparison of the third interdigital nerve in patients with Morton's metatarsalgia and control patients. *Aust N Z J Surg*. 1994;64:421-424.
18. Addante JB, Peicott PS, Wong KY, Brooks DL. Interdigital neuromas: results of surgical excision of 152 neuromas. *J Am Podiatr Med Assoc*. 1986;76:493-495.
19. Jones R, Tubby AH. Metatarsalgia or Morton's disease. *Ann Surg*. 1897;28:297.
20. Mulder JD. The causative mechanism in Morton's metatarsalgia. *J Bone Joint Surg*. 1951;33-B:94-95.
21. Cloke DJ, Greiss ME. The digital nerve stretch test: a sensitive indicator of Morton's neuroma and neuritis. *Foot Ankle Surg*. 2006;12:201-203.
22. Owens R, Gougoulias N, Guthrie H, Sakellariou A. Morton's neuroma: clinical testing and imaging in 76 feet, compared to a control group. *Foot Ankle Surg*. 2011;17:197-200.
23. Wu KK. Morton's interdigital neuroma: a clinical review of its etiology, treatment, and results. *J Foot Ankle Surg*. 1996;35: 112-119.
24. Pastides P, El-Sallakh S, Charalambides C. Morton's neuroma: a clinical versus radiological diagnosis. *Foot Ankle Surg*. 2012;18:22-24.
25. Park HJ, Kim SS, Rho MH, Hong HP, Lee SY. Sonographic appearances of Morton's neuroma: differences from other interdigital soft tissue masses. *Ultrasound Med Biol*. 2011;37:1204-1209.
26. Quinn TJ, Jacobson JA, Craig JG, van Holsbeeck MT. Sonography of Morton's neuromas. *AJR Am J Roentgenol*. 2000;174:1723-1728.
27. Kaminsky S, Griffin L, Milsap J, Page D. Is ultrasonography a reliable way to confirm the diagnosis of Morton's neuroma? *Orthopedics*. 1997;20:37-39.
28. Read JW, Noakes JB, Kerr D, et al. Morton's metatarsalgia: sonographic findings and correlated histopathology. *Foot Ankle Int*. 1999;20:153-161.
29. Symeonidis PD, Iselin LD, Simmons N, et al. Prevalence of interdigital nerve enlargements in an asymptomatic population. *Foot Ankle Int*. 2012;33: 543-547.
30. Mendicino SS, Rockett MS. Morton's neuroma: update on diagnosis and imaging. *Clin Podiatr Med Surg*. 1997;14:303-311.
31. Zanetti M, Ledermann T, Zollinger H, Hodler J. Efficacy of MR imaging in patients suspected of having Morton's neuroma. *AJR Am J Roentgenol*. 1997;168:529-532.
32. Fazal MA, Khan I, Thomas C. Ultrasonography and magnetic resonance imaging in the diagnosis of Morton's neuroma. *J Am Podiatr Med Assoc*. 2012;102:184-186.
33. Bencardino J, Rosenberg ZS, Beltran J, Liu X, Marty-Delfaut E. Morton's neuroma: is it always symptomatic? *AJR Am J Roentgenol*. 2000;175:649-653.
34. Sharp RJ, Wade CM, Hennessy MS, Saxby TS. The role of MRI and ultrasound imaging in Morton's neuroma and the effect of size of lesion on symptoms. *J Bone Joint Surg Br*. 2003;85:999-1005.
35. Bennett GL, Graham CE, Mauldin DM. Morton's interdigital neuroma: a comprehensive treatment protocol. *Foot Ankle Int*. 1995;16:760-763.
36. Saygi B, Yildirim Y, Saygi EK, Kara H, Esemenli T. Morton neuroma: comparative results of two conservative methods. *Foot Ankle Int*. 2005;26:556-559.
37. Kilmartin TE, Wallace WA. Effect of pronation and supination orthosis on Morton's neuroma and lower extremity function. *Foot Ankle Int*. 1994;15:256-262.
38. Finney W, Wiener SN, Catanzariti F. Treatment of Morton's neuroma using percutaneous electrocoagulation. *J Am Podiatr Med Assoc*. 1989;79:615-618.
39. Genon MP, Chin TY, Bedi HS, Blackney MC. Radio-frequency ablation for the treatment of Morton's neuroma. *ANZ J Surg*. 2010;80:583-585.
40. Moore JL, Rosen R, Cohen J, Rosen B. Radiofrequency thermoneurolysis for the treatment of Morton's neuroma. *J Foot Ankle Surg*. 2012;51:20-22.
41. Fridman R, Cain JD, Weil L Jr. Extracorporeal shockwave therapy for interdigital neuroma: a randomized, placebo-controlled, double-blind trial. *J Am Podiatr Med Assoc*. 2009;99:191-193.
42. Younger AS, Claridge RJ. The role of diagnostic block in the management of Morton's neuroma. *Can J Surg*. 1998;41:127-130.
43. Dockery GL. The treatment of intermetatarsal neuromas with 4% alcohol sclerosing injections. *J Foot Ankle Surg*. 1999;38:403-408.
44. Hughes RJ, Ali K, Jones H, Kendall S, Connell DA. Treatment of Morton's neuroma with alcohol injection under sonographic guidance: follow-up of 101 cases. *AJR Am J Roentgenol*. 2007;188: 1535-1539.
45. Musson RE, Sawhney JS, Lamb L, Wilkinson A, Obaid H. Ultrasound guided alcohol ablation of Morton's neuroma. *Foot Ankle Int*. 2012;33:196-201.
46. Basadonna PT, Rucco V, Gasparini D, Onorato A. Plantar fat pad atrophy after corticosteroid injection for an interdigital neuroma: a case report. *Am J Phys Med Rehabil*. 1999;78:283-285.
47. Greenfield J, Rea J Jr, Ilfeld FW. Morton's interdigital neuroma: indications for treatment by local injections versus

surgery. *Clin Orthop Relat Res.* 1984;(185):142-144.

48. Rasmussen MR, Kitaoka HB, Patzer GL. Nonoperative treatment of plantar interdigital neuroma with a single corticosteroid injection. *Clin Orthop Relat Res.* 1996;(326):188-193.
49. Hassouna H, Singh D, Taylor H, Johnson S. Ultrasound guided steroid injection in the treatment of interdigital neuralgia. *Acta Orthop Belg.* 2007;73:224-229.
50. Markovic M, Crichton K, Read JW, Lam P, Slater HK. Effectiveness of ultrasound-guided corticosteroid injection in the treatment of Morton's neuroma. *Foot Ankle Int.* 2008;29:483-487.
51. Makki D, Haddad BZ, Mahmood Z, Shahid MS, Pathak S, Garnham I. Efficacy of corticosteroid injection versus size of plantar interdigital neuroma. *Foot Ankle Int.* 2012;33:722-726.
52. Gaynor R, Hake D, Spinner SM, Tomczak RL. A comparative analysis of conservative versus surgical treatment of Morton's neuroma. *J Am Podiatr Med Assoc.* 1989;79:27-30.
53. Amis JA, Siverhus SW, Liwnicz BH. An anatomic basis for recurrence after Morton's neuroma excision. *Foot Ankle.* 1992;13:153-156.
54. Nashi M, Venkatachalam AK, Muddu BN. Surgery of Morton's neuroma: dorsal or plantar approach? *J R Coll Surg Edinb.* 1997;42:36-37.
55. Faraj AA, Hosur A. The outcome after using two different approaches for excision of Morton's neuroma. *Chin Med J (Engl).* 2010;123:2195-2198.
56. Akermark C, Crone H, Saartok T, Zuber Z. Plantar versus dorsal incision in the treatment of primary intermetatarsal Morton's neuroma. *Foot Ankle Int.* 2008;29:136-141.
57. Barrett SL, Pignetti TT. Endoscopic decompression for Morton's neuroma: preliminary study with cadaveric specimen: early clinical results. *J Foot Ankle Surg.* 1994;33:503-508.
58. Shapiro SL. Endoscopic decompression of the inter-metatarsal nerve for Morton's neuroma. *Foot Ankle Clin.* 2004;9:397-407.
59. Dellon AL. Treatment of Morton's neuroma as a nerve compression: the role for neurolysis. *J Am Podiatr Med Assoc.* 1992;82:399-402.
60. Diebold PF, Daum B, Dang-Vu V, Litchinko M. True epineural neurolysis in Morton's neuroma: a 5-year follow up. *Orthopedics.* 1996;19:397-400.
61. Okafor B, Shergill G, Angel J. Treatment of Morton's neuroma by neurolysis. *Foot Ankle Int.* 1997;18:284-287.
62. Vito GR, Talarico LM. A modified technique for Morton's neuroma: decompression with relocation. *J Am Podiatr Med Assoc.* 2003;93:190-194.
63. Villas C, Florez B, Alfonso M. Neurectomy versus neurolysis for Morton's neuroma. *Foot Ankle Int.* 2008;29:578-580.
64. Barrett SL, Rabat E, Buitrago M, et al. Endoscopic decompression of intermetatarsal nerve (EDIN) for the treatment of Morton's entrapment: multicenter retrospective review. *Open J Orthop.* 2012;2:19-24.
65. Mann RA, Reynolds JC. Interdigital neuroma: a critical clinical analysis. *Foot Ankle.* 1983;3:238-243.
66. Colgrove RC, Huang EY, Barth AH, Greene MA. Interdigital neuroma: intermuscular neuroma transposition compared with resection. *Foot Ankle Int.* 2000;21:206-211.
67. Coughlin MJ, Pinsonneault T. Operative treatment of interdigital neuroma: a long-term follow-up study. *J Bone Joint Surg Am.* 2001;83-A:1321-1328.
68. Akermark C, Saartok T, Zuber Z. A prospective 2-year follow-up study of plantar incisions in the treatment of primary intermetatarsal neuromas (Morton's neuroma). *Foot Ankle Surg.* 2008;14:67-73.
69. Valente M, Crucil M, Alecci V. Operative treatment of interdigital Morton's neuroma. *Chir Organi Mov.* 2008;92:39-43.
70. Pace A, Scammell B, Dhar S. The outcome of Morton's neurectomy in the treatment of metatarsalgia. *Int Orthop.* 2010;34:511-515.
71. Lee KT, Kim JB, Young KW, et al. Long-term results of neurectomy in the treatment of Morton's neuroma: more than 10 years' follow-up. *Foot Ankle Spec.* 2011;4:349-353.
72. Young G, Lindsey J. Etiology of symptomatic recurrent interdigital neuromas. *J Am Podiatr Med Assoc.* 1993;83:255-258.
73. Wolfort SF, Dellon AL. Treatment of recurrent neuroma of the interdigital nerve by implantation of the proximal nerve into muscle in the arch of the foot. *J Foot Ankle Surg.* 2001;40:404-410.