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General

Clinical Results Following Conservative Management of Tarsal Tunnel Syndrome Compared With Surgical Treatment: A Systematic Review

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Introduction

Posterior tarsal tunnel syndrome involves entrapment of the posterior tibial nerve as it travels in the groove posterior to the medial malleolus. Conventional wisdom dictates that patients with tarsal tunnel syndrome be treated with conservative treatment and medical management, with surgical options available for patients with refractory symptoms and good candidacy. Minimally invasive options for neuropathic entrapment syndromes have developed in recent years and may provide a therapeutic role in tarsal tunnel syndrome.

Objective

The present investigation provides a summary of the current state of knowledge on tarsal tunnel syndrome and a comparison between minimally invasive and surgical treatment options.

Methods

The literature search was performed in Mendeley. Search fields were varied until redundant. All articles were screened by title and abstract and a preliminary decision to include an article was made. A full-text screening was performed on the selected articles. Any question regarding the inclusion of an article was discussed by 3 authors until an agreement was reached.

Results

Most commonly tarsal tunnel syndrome is idiopathic. Other reported causes include post-traumatic, lipomas, cysts, ganglia, schwannomas, ganglia, varicose plantar veins, anatomic anomalies, and systematic inflammatory conditions. Several risk factors have been described including female gender, athletic participation, hypothyroidism, diabetes mellitus, systemic sclerosis, chronic renal failure, and hemodialysis use. A few recent studies demonstrate anatomic variants that have not previously been summarized. Three articles describe clinical outcomes after conservative treatment with acceptable results for first line treatment. Two primary articles report on the use of minimally invasive treatment for tarsal tunnel syndrome. Fourteen articles report on the clinical outcomes after surgical management.

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Conclusion

Clinical understanding of tarsal tunnel syndrome has evolved significantly, particularly with regards to the pathoanatomy of the tarsal canal over the past twelve years. A few novel anatomic studies shed light on variants that can be helpful in diagnosis. Conservative management remains a good option that can resolve the symptoms of many patients. As more prospective cohorts and clinical trials are performed on minimally invasive options, pulsed radiofrequency and neuromodulation may evolve to play a larger role in the treatment of this condition. Currently, surgical treatment is only pursued in a very select group of patients with refractory symptoms that do not respond to medical or minimally invasive options. Surgical outcomes in the literature are good and current evidence is stronger than that for minimally invasive options.

1. INTRODUCTION

Tarsal Tunnel Syndrome (TTS) is an uncommon clinical entity resulting from the compression of the tibial nerve coursing behind the medial malleolus underneath the flexor retinaculum into the plantar surface of the foot. TTS is sometimes referred to as posterior tibial nerve entrapment of the ankle. The condition was first recognized in 1933 by Koppel and Thompson as a post-traumatic peripheral nerve compression, but it was not until 1962 that the condition became known as "tarsal tunnel syndrome" and its clinical presentation related to its corollary of the hand, carpal tunnel syndrome.[1] Like most entrapment neuropathies, TTS presents in a variety of fashions and is complicated in that compression may be complete or partial, such that motor and/or sensory fiber involvement may be affected to varying degrees.[1,2]

At present, almost a century since its first description, TTS has been further characterized with regard to pertinent anatomy, epidemiology, etiology, pathophysiology, clinical presentation, and treatment.[2] The purpose of the present review, therefore, is to summarize TTS and describe its current treatment options.

2. MATERIALS AND METHODS

SEARCH STRATEGY

The literature search was performed using Medical Search Headings (MeSH) in Mendeley version 1.19.8. Articles published between January 1975 to December 2021 were Search fields were varied until no new articles were collected at which point the search was considered exhaustive.

STUDY SCREENING AND SELECTION

All articles were screened by title and abstract. An initial decision to include a given article was made based on relevance of the information within the abstract as determined by our inclusion/exclusion criteria (**Table 1**). This constructed a list of preliminarily included articles. These articles then underwent a full-text screening process. Any question regarding the inclusion of an article was discussed by all authors until an agreement was reached. The bibliographies of these articles were also hand-searched to identify any missing articles.

Table 1. Inclusion and exclusion criteria as applied during the title/abstract screening and full-text screening.

Inclusion Criteria	Exclusion Criteria
• Publication between 1975 - 2022 • Use of conservative, minimally invasive, or surgical treatment options for tarsal tunnel syndrome • Level IV evidence and higher	• Absence of a conservative, minimally invasive, or surgical treatment option • Expert Opinion or Case Reports

3. RESULTS

3.1. EPIDEMIOLOGY

TTS is a relatively uncommon entrapment neuropathy and is one of several entrapment neuropathies of the ankle. A numerical estimate of the prevalence of TTS has not been presented, however, estimates of a few studies report that it is likely underdiagnosed.[2–4] TTS is the fifth most commonly entrapment syndrome based on comparative estimates between studies.[5] There does not appear to be a preferential age distribution for TTS though these waters may be muddied with delay in presentation and misdiagnosis. TTS more commonly presents in active patients, likely due to repetitive stress to the peri-articular ankle region.[6,7]

3.2. ETIOLOGY

TTS can be due to several reasons, most all of which however involve compression of the tibial nerve or one of its branches as it courses posterior to the medial malleolus and onto the palmar surface of the foot. TTS generally presents idiopathically between 18% to 57% of the time.[8] Other causes include post-traumatic,[3] lipomas,[5] cysts,[5] ganglia,[5] schwannomas,[5] ganglia,[5] varicose plantar veins, anatomic anomalies,[2,9,10] and systematic inflammatory conditions.[9,10]

Most commonly, TTS arises post-traumatically as a result of fibrosis of the tissues periarticular to the ankle, injury to the ligament (often the medially located deltoid ligament), or boney changes.[3] For similar reasons, TTS is also described to be more common in athletes, especially long-distance runners, who repeatedly stress the peri-articular ankle region.[6,7,11] Space-occupying lesions (excluding vari-

cosities) such as lipomas, cysts, and ganglia account for roughly 20% of TTS cases, and is halved when considering only tumorigenic etiologies such as schwannomas and ganglia.[5] Varicose plantar veins and other conditions associated with venous return supply are thought to explain TTS etiology in roughly 17-25% cases, although a recent ultrasound-based study of 80 TTS patients found this number to be slightly higher at 31%.[12] Muscle-related disorders are also seen in TTS patients. Patients with hypertrophied muscles which cross the ankle joint, such as the abductor hallucis muscle, may present with TTS. Anatomic anomalies, such as the presence of the flexor digitorum accesorius longus or accessory abductor hallucis muscles have also been implicated as they impinge on the nerve.[2,9,10]

Other local etiologies of TTS include tenosynovitis, edema, tarsal coalition, and hypertrophied flexor retinacula.[13] TTScan also be caused by systemic pathologies, such as rheumatoid arthritis and inflammatory arthropathies, including synovitis.[9,10] Many systemic pathologies are also associated with TTS, including collagen-related diseases, hypothyroidism, diabetes mellitus, acromegaly, diabetes, and even sclerosis.[13,14]

3.3. RISK FACTORS

Demographic risk factors for the development of posterior tarsal tunnel syndrome include athletic participation, individuals who experience prolonged periods of repetitive weight-bearing activities[4,7] and the female gender.[1,2] Several preexisting medical conditions have also been identified as risk factors. Any include pathophysiological process that expand the volume of soft tissues within tarsal tunnel could theoretically cause tarsal tunnel syndrome through a pressure-mediated effect. Though few robust studies have examined the risk factors, a few case series and small studies have evaluated the presence of tarsal tunnel syndrome in specific groups. Identified medical conditions include hypothyroidism, diabetes mellitus, systemic sclerosis, chronic renal failure.[4,7,15–21]The myxedema that occurs in hypothyroidism can lead to tarsal tunnel syndrome from the increased swelling of tissues in the tarsal tunnel.[17] Patients affected by diabetes mellitus have higher rates of tarsal tunnel syndrome due to the chronic compression of the posterior tibial nerve which can further lead to diabetic foot ulceration.[18,19] Hemodialysis patients were found to have tarsal tunnel syndrome with rates up to 0.5% with increasing prevalence as maintenance dialysis went beyond 5 years most likely due to the deposition of beta-2 microglobulin.[21]

3.4. ANATOMY AND PATHOANATOMY

The tarsal tunnel is a fibro-osseous channel with borders comprised of the medial malleolus anterosuperiorly, the talus posteriorly, and calcaneus laterally.[22] The tarsal tunnel is anchored by the flexor retinaculum extending from the medial malleolus to the medial calcaneus and prevents the displacement of its contents (oriented from medial to lateral) - posterior tibialis tendon, flexor digitorum longus tendon, posterior tibial artery and vein, posterior tibial nerve (L4-S3), and flexor hallucis longus tendon.[23,24] The posterior tibial nerve bifurcates in the tarsal tunnel into the medial and plantar nerves, but in 5% of people the nerve bifurcates before the tarsal tunnel.[25] The medial plantar nerve provides motor innervation to the lumbricals, abductor hallucis, flexor digitorum brevis, and flexor hallucis brevis and sensation to the medial half of the foot and first 3.5 digits.[26] It passes deep to the abductor hallucis and flexor hallucis longus muscle.

Whereas the lateral plantar nerve directly enters the belly of the abductor hallucis muscle providing motor innervation to the flexor digitorum brevis, quadratus plantae, and abductor digiti minimi and sensory innervation to the medial calcaneus and lateral heel. The medial calcaneal nerve provides sensory innervation to the posteromedial heel and branches off the posterior tibial nerve proximal to the tunnel; in about a quarter of patients, it branches off the lateral plantar nerve or can run superficial to the flexor retinaculum.[27]

Tarsal tunnel syndrome stems from the compression of the posterior tibial nerve, the lateral plantar, or medial plantar within the tunnel secondary to structural, pathologic, or biomechanical factors.[22,28–30] Since the tarsal tunnel is a confined space any anatomical or pressure changes may lead to pathology and can compress the neurovascular structures.[4] Nearly half of affected patients have had some trauma to the tarsal tunnel leading to scar tissue, bone or cartilage fragments, or bony spurs that may compress the nerve.[3]

3.5. CLINICAL PRESENTATION

Patients with tarsal tunnel syndrome (TTS) most commonly present with intermittent anesthesia, paresthesia, or dysesthesia along the plantar aspect of the foot, most often described as a burning pain.[16,31,32] The onset of pain is frequently insidious especially in idiopathic cases or it can begin after a trauma to the ankle.[31] The numbness or pain correlates with which portion of the tibial nerve is involved, meaning if the medial plantar nerve is involved the medial aspect of the foot will be where symptoms occur.[33] The pain often radiates distally to the entrapment and may involve the toes.[34] Rarely the numbness and pain can radiate proximal to the entrapment and involve the calf, this is known as the Valleix phenomenon.[31,32] If more distal branches of the nerve are involved, weakness of the abductor hallucis may occur.[35] Weakness in the smaller intrinsic muscles of the foot can rarely be appreciated on clinical exam.[16] The pain often worsens after prolonged standing or at night.[16,31] Symptoms are typically relieved with rest and elevation of the foot.[31] Neurological exam can show decreased sensation to touch and pinprick and some weakness in toe flexion, although, sensory testing typically is not revealing.[16,35] Percussion over the tibial nerve posterior to the medial malleolus will reproduce the symptoms indicating a positive Tinel's sign.[16,31,32] Sustained eversion or inversion or digital compression of the nerve can also reproduce the symptoms.[31] Exam should also assess for space occupying lesions that may be contributing to the pain or compressing the nerve.[35] A though history and

exam should be performed to rule out other neuropathic conditions that may be causing the pain.[35,36]

3.6. DIAGNOSIS

To make a diagnosis of TTS the patient should have pain or dysesthesia in the area supplied by the tibial nerve, a positive Tinel's sign, and electrophysiological studies, electromyography (EMG) or nerve conduction studies (NCS), showing decreased nerve conduction.[14,32] Electrophysiological studies are the most reliable ways to confirm TTS.[31] NCS will typically show reduced sensory action potentials and a decrease in conduction speed velocity.[16] There may also be reductions in motor conduction velocity and compound muscle action potential amplitude, but those findings less sensitive compared to sensory nerve conduction studies.[16,35] When compared to other nerve entrapment syndromes, electrophysiological testing is less sensitive in TTS.[37] Imaging can be done to evaluate for space-occupying lesions, bony deformities or evidence of nerve entrapment.[31,32,37] Plain radiographs can be used to assess for bony deformities and weight-bearing films should be done on patients with suspected TTS to also assess heal alignment.[31,35] Ultrasound can be useful to assess for space occupying lesions and assessing the anatomy of the patient and can also asses for pressures within the tarsal tunnel.[38–40] MRI is useful for treatment planning in addition to assessing for space occupying lesions that could be causing the TTS.[32,35,39] MRI in patients with TTS will show an abnormality in 85% of patients and can thus be a useful diagnostic tool.[35] Electrophysiologic studies and imaging can both assess for other neuronopathic conditions causing the symptoms instead of TTS and ensure patients receive appropriate treatments.[16]

3.7. CONSERVATIVE TREATMENT

TTS is generally managed conservatively, and medical management should be thoroughly attempted before initiating minimally invasive or surgical treatments. Our literature search revealed 3 articles that explored the clinical outcomes of conservative treatment in tarsal tunnel syndrome (see **Table 2**). In general, conservative treatment consists of rest, non-steroidal anti-inflammatory drugs (NSAIDs), foot orthoses (often for foot-deformity-derived TTS), physiotherapy/stretching exercises, and local anesthetics such as corticosteroid injections[41] and local anti-inflammatory salves. Use of NSAIDs and corticosteroid injections appear to be most effective for inflammatory-related etiologies such as tenosynovitis or rheumatoid arthritis.[9,42,43] Other conservative treatments indicated for TTS include extracorporeal shock wave therapy, laser, heel cups, heel pads, night splints, and arch supports.[44,45] However, it is worth mentioning that the current literature is inconclusive regarding the use of arch supports for the treatment of.[44,45]

Regarding TTS, conservative treatment is often indicated for patients with mild to moderate pain and less foot comorbidities.[14] The most recent empirical work looking at conservative TTS treatment found improvement in both pain and range of motion for all 28 patients when patients followed a robust 6-week physiotherapy program which included stretching, muscle strengthening exercises, and the use of medial arch supports as well as wedges.[44]

3.8. MINIMALLY INVASIVE TREATMENTS

The results of our literature search did not return any randomized controlled trials or cohort studies regarding the clinical efficacy of minimally invasive treatment of tarsal tunnel syndrome.[2–4,46,47] Publications exist but are limited to case series and detailing the use of minimally invasive treatments such as cryosurgery[48] and radio pulsed frequency.[49] These are summarized in **Table 3**. Cryosurgery is a possible option when conservative management has failed with an early study demonstrating empirical effectiveness.[4,48] Cryosurgery has shorter recovery periods, no need for an operating room, no potential for scar formation, and complete functional capability after cryosurgery is completed.[4,48] Despite the empirical success, its usefulness is limited by few studies of cryosurgery in the treatment of tarsal tunnel syndrome. Pulsed frequency is another minimally invasive treatment modality with some potential in tarsal tunnel syndrome. Pulsed radiofrequency is generally conducted under ultrasound in two patients demonstrated a reduction in the visual analog scale (VAS) scores from 8-9 to 2-3 at 12 month follow up in one patient and 8 to 2 after two rounds of radiopulsed frequency in the second patient at the 8 month follow up.[49,50] Though providing promising data, this case series is isolated and limited by level of evidence. Large scale cohort studies and clinical trials would be needed before definitive statements regarding the clinical efficacy of minimally invasive treatments in tarsal tunnel syndrome could be made.

3.9. SURGICAL TREATMENTS

Surgical treatment of TTS aims to alleviate the nerve entrapment by decompressing the densely packed neurovascular space of the posterior tarsal tunnel.[37,51,52] The results of our literature search revealed fourteen primary studies reporting on the clinical outcomes after surgical management of tarsal tunnel syndrome. These are summarized in **Table 4**.

Important to the discussion of surgical treatment is patient selection. Surgical intervention may be the appropriate next step for patients in whom medical management and minimally invasive treatment options fail.[14,36] The success rate of conservative treatment is not clear and should be tried before proceeding with surgery.[14,38] Patients with a known cause of TTS, such as a space occupying lesion or history of trauma, are more likely to have a satisfactory result after surgery than patients with idiopathic TTS.[34,52] Comorbid obesity and diabetes decrease the likelihood of having a good surgical outcome.[14,53]

4. CONCLUSIONS

Tarsal tunnel syndrome is the fifth most common entrapment syndrome and can occur at any age. It is generally

Table 2. A summary of the three published outcome studies revealed by our literature search on the conservative treatment of tarsal tunnel syndrome.

Lead Author	Year	Journal	Institution	Study Type	Level of Evidence	Number of Patients	Success Measure	Success Rate	Complication Rate	Reported Complications	Length of Follow-Up
William Gondring	2009	Foot and Ankle Surgery	Heartland Health, St. Joseph, MO, USA	Prospective		56	Pain Scale, Satisfaction	17/56	2/56	Brace leading to sleep problems	4 weeks mean (1-12 range)
Yasemin Kavlak	2011	Journal of Manipulative and Physiological Therapeutics	Orthotic RehabilitationDepartment of Hacettepe University, Ankara	Prospective		14	ROM, Muscle Strength, Pain Severity, 2-point discrimination (MCN, LPN, MPN), Light tough (MCN, LPN, MPN), Paresthesia, Tinel sign, TNST	ROM (.**01**), Muscle Strength (.**01**), Pain Severity (.**00**), 2-point discrimination (.28, .09, .71), Light tough (.06, .22, .73), Paresthesia (1.00), Tinel sign (1.00), TNST (.50)	None	None	6 weeks
Yasemin Kavlak	2005	Fizyoterapi Rehabilitasyon	Hacettepe University Department of Orthopedics and Traumatology	Prospective		17	Pain Intensity, Functional Foot Score, Symptom Severity Scale, Foot Functional Index, Ankle Mobility, Heel-Ankle Mobility, Arc Mobility, Total Limitation, Strength	Pain Intensity (< **.05**), Functional Foot Score (< **.05**), Symptom Severity Scale (< **.05**), Foot Functional Index (< **.05**) Ankle Mobility (> .05) Heel-Ankle Mobility (< **.05**) Arc Mobility (< **.05**) Total limitation (< **.05**) Strength (< **.05**)	None	None	6 weeks

Table 3. A summary of the two published studies exploring minimally invasive treatments as revealed by our literature search in the treatment of tarsal tunnel syndrome.

Lead Author	Year	Journal	Institution	Modality Studied	Level of Evidence	Number of Patients	Success Measure	Success Rate	Reported Complications	Length of Follow-Up
Goldstein	2006	Podiatry Management	Not available ("private practice" mentioned in methods)	Cryoneurolysis	IV (Case Series)	13	VAS score	70%	None reported	6-12 weeks
Chon	2014	Journal of Anesthesia	Catholic University of Korea	Pulsed radiofrequency	IV (Case Series)	2	VAS score	100%	None Reported	8 or 12 months

Table 4. A summary of the fourteen published studies with clinical outcomes for surgical intervention of tarsal tunnel syndrome.

Lead Author	Year	Journal	Institution	Study Type	Level of evidence	Number of patients	Surgical procedure	Success Measure	Success Rate	Complication Rate	Reported Complications	Length of follow up
William H. Gondring M.D.[8]	2009	Foot and Ankle Surgery	Heartland Health	Prospective cohort	Level I	32	Tarsal Tunnel Release	Nursing history assessment, patient questionnaire, visual anatomic pain scale	All patients were satisfied	1 reported	Wound dehiscence	5 weeks
Xin Yu[4]	2020	Cell and Tissue Banking	First Hospital of Jilin University	Case series	Level IV	107	Singh method and non-singh method Tarsal Tunnel Release	Takakura evaluation criteria	62% had excellent or good outcomes	15/107	poor post operative outcome, Transient ischemia attack, long term pain medication use	5-74 months, avg-26 months
Masatoshi Yunoki[13]	2020	Asian Journal of Neurosurgery	Kagawa Rosai Hospital	Case series	Level IV	5	Tarsal Tunnel Release	Takakura evaluation criteria, Mondelli's scale	4 of 5 good or excellent	2 of 5	fluid leakage from the wound	none reported
Murat Gulcek[7]	2019	Foot and Ankle Surgery	Ankara Numune Education and Research Hospital, Ankara, Turkey	Case series	Level IV	66	Tarsal Tunnel Release	FFI index and questionnaire	45.1% very satisfied, 16.9% minor symptoms	18% no improvement, 18.3% continued symptoms	Not satisfied	9 years
Paweł Reichert[10]	2015	Foot and Ankle Surgery	Wroclaw Medical University	Case series	Level IV	31	Tarsal Tunnel Release	Vas and AOFAS scores	71% good/very good, 22% satisfactory	7% reported bad, 2% reported unsatisfactory	Bad, unsatisfactory surgical outcomes	12 months
Kyongsong Kim[15]	2014	Neurologia Medico-Chirurgica	Chiba Hokuso Hospital	Case series	Level IV	69	Neurovascular bundle decompression	Patient self satisfaction assessments	47 of 69 were satisfied	9/69	Surgical failure	none reported
Ki-sun Sung[14]	2009	Foot and Ankle International	Sungkynkwan University	Case series	Level IV	20	Tarsal Tunnel Release	VAS and AOFAS scores, subjective satisfaction	54% satisfied	15/107	numbness, tingling, hypoesthesia	14.5 months
J. Jerosch[5]	2006	Foot and Ankle	Johanna-Etienne	Case series	Level IV	75	Tarsal Tunnel Release	Vas and AOFAS scores	43/75 satisfied, 53/75	Number not reported	Superficial Wound	6-100 months

Lead Author	Year	Journal	Institution	Study Type	Level of evidence	Number of patients	Surgical procedure	Success Measure	Success Rate	Complication Rate	Reported Complications	Length of follow up
		Surgery	Hospital						improved VAS		infections	(avg 39 months)
William H. Gondring M.D.[23]	2003	Foot and Ankle International	Heartland Health	Case series	Level IV	60	Tarsal Tunnel Release	Objective and Subjective symptom relief	85% objective, 51% subjective	none reported	n/a	None reported
G. James Sammarco[2]	2003	Foot and Ankle International	Tulane University School of Medicine	Case series	Level IV	62	Tarsal Tunnel Release	MFS and AOFAS scores	Statistically significant improvement in MFS scores postoperatively	none reported	n/a	58 months
Michihiro Kohno[9]	2000	Journal of Neurology Neurosurgery and Psychiatry	Tokyo Medical University	Case Series	Level IV	9	Tarsal tunnel opening and neurovascular decompression	Resolution on sensory disturbance	6 complete resolution, 3 partial resolution	none reported	n/a	26.8 months
Akira Mori[20]	1997	Orthopedics and Traumatology	Fukuoka University Chikushi Hospital	Case series	Level IV	6	Tarsal Tunnel Release	Sensory recovery	all patients had sensory recovery	none reported	n/a	none reported
Tetsuki Sato[21]	1991	Orthopedics and Traumatology	Fukuoka University Chikushi Hospital	Case series	Level IV	10	Tarsal Tunnel Release	Sensory recovery	all patients had sensory recovery	none reported	n/a	none reported
Yoshinori Takakura[22]	1991	Journal of Bone and Joint Surgery	Nara Medical Univsersity	Case series	Level IV	45	Tarsal Tunnel Release	Takakura evaluation criteria	Not reported	none reported	n/a	4 years 9 months on average

idiopathic but can be due to post-traumatic inflammation, lipomas, cysts, ganglia, schwannomas, ganglia, varicose plantar veins, anatomic anomalies, and systematic inflammatory conditions. Our understanding the pathoanatomy of the tarsal canal over the past twelve years with recent cadaveric studies highlighting important anatomic variants that may prove useful in extending treatment options. Conservative management remains a good option that can resolve the symptoms of many patients. As more prospective cohorts and clinical trials are performed on minimally invasive options, pulsed radiofrequency and neuromodulation may evolve to play a larger role in the treatment of this condition. Surgical outcomes are described in the literature as good and current evidence is stronger than that for minimally invasive options. However, surgical treatment should only be pursued very select group of patients with refractory symptoms that do not respond to medical or minimally invasive options.

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FURTHER INFORMATION

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