Review Article

Pain on the Plantar Surface of the Foot

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Summary

Background: Plantar fasciitis (PF) is characterized by pain on weight-bearing in the medial plantar area of the heel, metatarsalgia (MTG) by pain on the plantar surface of the forefoot radiating into the toes. Reliable figures on lifetime prevalence in Germany are lacking.

Methods: This review is based on pertinent publications retrieved from a selective search in PubMed, on guidelines from Germany and abroad, and on the authors' clinical experience.

Results: Plantar fasciitis is generally diagnosed from the history and physical examination, without any ancillary studies. In 90–95% of cases, conservative treatment (e.g., stretching exercises, fascia training, ultrasound therapy, glucocorticoid injections, radiotherapy, shoe inserts, and shock-wave therapy) brings about total, or at least adequate, relief of pain within one year. Intractable pain is an indication for surgical treatment by plantar fasciotomy and/or calf muscle release. In metatarsalgia, a directed diagnostic work-up to find the cause is mandatory, including a search for excessive mechanical stress due to abnormal foot posture, neuropathic pain, rheumatoid arthritis, aseptic bony necrosis, or malignant disease; imaging studies and pedobarography are needed. For causally oriented treatment, a wide range of conservative and surgical measures can be considered.

Conclusion: The reported results of treatments for plantar fasciitis and metatarsalgia are heterogeneous. The efficacy of the individual measures should be studied in randomized controlled trials.

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Pain on the plantar surface of the foot subsumes constellations of symptoms arising from various underlying conditions. In this article we present the clinical findings of the diseases that most commonly cause plantar pain, the diagnostic procedures available, and an overview of the treatment options. For reasons of space we restrict ourselves to the two most highly prevalent conditions, plantar fasciitis and metatarsalgia.

Methods

We carried out a selective survey of the literature in the PubMed database. The search terms were “metatarsalgia”, “transfer metatarsalgia”, “Morton neuroma”, “Freiberg disease”, “Freiberg’s infraction”, “plantar fasciitis”, “plantar spur”, and “heel pain.” We also took account of national and international recommendations and our own experience.

Plantar fasciitis

Symptoms and clinical picture

Patients with plantar fasciitis (PF) complain of pain in the medial plantar part of the heel. The pain occurs when they take the first steps after getting out of bed in the morning or following a period of inactivity. After initial improvement, the pain worsens in the course of the day.

Epidemiology

Plantar fasciitis is a common disease with peak occurrence between 45 and 65 years of age (1–3). A systematic review of 8 studies with a total of 3500 patients found a prevalence of 5.2 to 17.5% in active runners (4). PF can, however, occur as early as in childhood (5).

Anatomy and biomechanics

The plantar fascia (synonym: plantar aponeurosis) is made up of connective tissue and runs from the calcaneus to the toes. The plantar fascia forms, together with the plantar calcaneonavicular ligament and the long plantar ligament, the passive tensioning structures for the longitudinal bony arch of the foot and possesses a pulley-like mechanism providing a suspensory function. At the same time it offers points of origin and insertion for the short plantar muscles of the foot.

Pathogenesis and risk factors

Plantar fasciitis is multifactorial in origin and is viewed as a mechanical overloading reaction to multiple instances of microtrauma. The risk factors are thought to be shortening of the calf muscles, overweight, long periods of employment in nonsedentary occupations, and deformities of the foot. The accumulated occurrence of

Figure 1: Female patient with severe metatarsalgia in bilateral recurrent hallux valgus and floating toes following bilateral hallux valgus correction and Weil osteotomy: a) plantar view; b) anterior view.

PF in persons with a body mass index (BMI) >27 (odds ratio 3.7, 95% confidence interval [2.93; 5.62]) was confirmed in an exhaustive meta-analysis (6).

In around 83% of cases the PF was associated with shortened calf muscles (7). The resulting restriction of dorsal flexion in the ankle joint (AJ) forces the calcaneus into excessive pronation, thus increasing the distance between the calcaneus and the toes. This is associated with greater tension on the plantar fascia (8). Dorsal flexion of $\leq 0^\circ$ in the AJ elevates the risk of PF by a factor of 23 [4.3; 124.4] compared with dorsal flexion of at least 10° (9). Rubin et al. found a plantar heel spur on the radiographs of 27% of 461 probands with no clinical symptoms (10). Ahmad et al. investigated 109 patients with PF, of whom 23.6% did not have a heel spur. The size and shape of the heel spur had no effect on the severity of pain or the degree of

functional limitation (11). The spur may also be completely separated or located within the intrinsic foot musculature and cause no symptoms (12, 13) (*eFigure 1*). Differential diagnoses that must be considered are tendinitis of the flexor hallucis longus tendon and posterior impingement of the AJ (14).

Clinical examination

Together with the patient's medical history, clinical examination suffices for reliable detection of PF (15). The Silfverskjöld test is helpful for determining the presence of shortened calf muscles. The pain can be provoked by palpation of the area of insertion of the plantar fascia to the calcaneal tubercle and intensified by forced dorsal flexion of the lesser toes.

Diagnostic imaging

In a retrospective study, 17.2% of the radiographs showed no abnormality (16). A plantar heel spur was present in 59.5% of cases, and 46.5% of the patients had an Achilles heel spur. However, only in 2% of cases did the additional information lead to alteration of the treatment strategy (for instance, surgical drainage of a bony cyst). Therefore, diagnostic radiography is recommended only in the presence of pain that has not responded to treatment (17). There is no consensus on the diagnostic power of other imaging modalities (magnetic resonance imaging [MRI], sonography). Thickening of the plantar fascia (>4 mm) is often associated with a local reaction, but is also found (in $>21\%$ of cases) in asymptomatic patients (18).

Treatment

Pain relief can be achieved by conservative means in 90% of patients within 6 months. PF is generally thought to be self-limiting within 1 year from onset, but this has not been confirmed by published research (19). An overview of the efficacy of the various treatment options is given below.

Conservative treatment

The administration of nonsteroidal antirheumatic drugs (NSARD) may be helpful in the acute stage of PF. Donley et al. found that addition of NSARD treatment to stretching programs and use of insoles differed only very slightly from placebo in terms of treatment success (20).

Factors that lead to chronic overload and exertion of tension on the plantar fascia should always be considered when deciding on the appropriate treatment (e.g., weight loss in the case of high BMI) (5). A meta-analysis showed that use of insoles to relieve the medial segment of the longitudinal arch of the foot is associated with significant pain reduction and functional improvement (21).

The general recommendations are regular stretching of the calf muscles and the plantar fascia by means of specific exercises, eccentric exercising or fascia training of the AJ, and weight loss (5). On biomechanical grounds, despite the lack of randomized

controlled trials, it is beneficial to reduce the continuous tension on the insertion of the plantar fascia. Engkananuwat et al. succeeded in achieving complete freedom from pain in 56% of their patients ($n = 25$) with a 4-week program of combined stretching of the plantar fascia and the calf muscles. Digiovanni et al., investigating the long-term outcome of a standardized plantar fascia stretching program, reported freedom from pain in 92% of patients ($n = 66$) after 2 years' follow-up (22, 23).

The precise mechanisms of the established low-dose radiotherapy are not yet fully understood. Its anti-inflammatory effect is brought about by, among other factors, cytokine release, local modulation of pH, and improvement of tissue perfusion (24–26). Several studies have confirmed pain reduction in 60 to 90% of patients (27–31). If required, the radiotherapy cycle can be repeated. After a second cycle, 75% of the patients in one study reported complete regression of their symptoms (32). In another study, no adverse effects (local tissue toxicity, tumor induction) of low-dose radiotherapy of the extremities were found over an 8-year observation period (33). Three-month follow-up in a randomized trial with 128 patients showed significantly greater pain reduction in the radiotherapy group (six fractions, 1 Gy) than in the glucocorticoid injection group (34).

In a multicenter study, local glucocorticoid injections in the acute phase of PF achieved average pain reduction of 6.4 points $[-11.1; -1.6]$ on a visual analog scale (VAS; scale of 0 to 100). The effect was limited to 4 weeks after injection and the evidence level was low (35). Therefore monotherapy is not advised (16). In view of the adverse effects (uncommon though they are) such as atrophy of the plantar fat pad or rupture of the plantar fascia (in 2.4% of patients after an average of three injections [36]), restriction to no more than two to three injections per year is recommended (16).

Successful clinical application of various other injection techniques, such as needling, platelet-rich plasma, and injections of botulinum toxin, has been described. However, the absence of research data means that no general treatment recommendation can currently be formulated.

Ultrasound treatment was found to have pain-relieving effects in several studies (37–39). However, a randomized, placebo-controlled double-blind trial showed that addition of ultrasound treatment to a stretching program had no positive effect on pain reduction or function. The authors recommended that ultrasound no longer be used in the treatment of PF (40).

About 70% of patients treated with extracorporeal shockwave therapy (ESWT) reported significant alleviation of pain around week 12 of disease (e1–e5). One study showed that ESWT was inferior to stretching programs (e6), while another comparative analysis found it to be more effective than ultrasound treatment (39). ESWT is currently not a first-line

Figure 2: Pedobarographic image with high peak pressures over the metatarsal heads (left); postoperative pressure distribution after hallux valgus correction and distal minimally invasive metatarsal osteotomy (right). (Color key: increased pressure from black to red)

treatment, and German health insurance providers usually do not cover the costs. In view of the low rate of adverse effects, however, it is a useful option in cases where other conservative treatments have been unsuccessful.

Surgical treatment

Surgical treatment comes into play when conservative treatment has been unsuccessful in relieving the symptoms. In 90 to 95% of patients, combined conservative treatment measures achieve adequate pain relief within 12 months (e7, e8). Complete or partial plantar fasciotomy (so-called release) brings about direct relief of the tension in the area of the insertion. This intervention can be performed by open surgery or endoscopically, with similarly good results. A retrospective study documented complete relief from symptoms for both procedures at 9 months after operation. The patients treated endoscopically were able to return to work a mean 55 days earlier (e9). Other studies found overall success rates of 94 to 96% for endoscopic release of the plantar fascia, but only 44.5% in patients with BMI $>29.8 \text{ kg/m}^2$ (e10, e11).

Moreover, indirect relief of the plantar fascia can be achieved through release of the usually shortened gastrocnemius muscle by transverse notching of the muscle fascia. The patient satisfaction rate was stated as 95% in the study concerned (e12). One year after the operation, 81% of patients ($n = 21$) reported pain relief (e13).

To what extent the combination of plantar fasciotomy and gastrocnemius release might increase the success rate has not yet been researched sufficiently.

Figure 3: a) Radiograph in dorsoplantar projection showing hallux valgus and increased sclerosis of the head of MT2 in Köhler disease II; b) radiographic follow-up after percutaneous hallux valgus correction with proximal displacement osteotomy of MT1 and Akin osteotomy and displacement osteotomy of MT2

Metatarsalgia

History and clinical examination

The term metatarsalgia describes a complex of symptoms associated with pain extending from the plantar forefoot into the toes.

Targeted questioning about the patient's medical history and clinical examination form the central pillars of diagnosis. The callosities on the feet (*Figure 1*) and the patterns of wear on the patient's shoes yield important pointers to the zones of excess load. Assessment of the stance, hindfoot axis, and longitudinal arch in normal standing and on tiptoe can yield pointers to, among other things, functional impairment of the tendon of the posterior tibial muscle (descent of the longitudinal arch in flat foot). The patient should be asked for information on current comorbidities and previous treatments, operations, and adaptations of footwear. In a diabetic patient, burning pain, usually independent of loading, could indicate polyneuropathy.

Dull, burning, and electrifying pains occasionally radiating to the toes, possibly accompanied by V-shaped divergence of the second and third toes (V or victory sign) are described in connection with Morton neuroma (perineural fibrosis) (e14).

A rupture of the so-called plantar plate may be responsible for claw toe (e15). If the MTP joint does not align on pressure to the planter aspect of the metatarsal head (Kelikian push-up test), rupture of the plantar plate must be assumed. There is also often a pressure point on the dorsal proximal interphalangeal joint from impingement of the joint against the upper of the shoe.

Epidemiology

There are no robust statistical data on the prevalence of metatarsalgia. The figures for hallux valgus deformity—often associated with metatarsalgia—can be used for orientation: global prevalence of around 23% in 18- to 65-year-olds and 35% in those over 65 (e16). However, metatarsalgia also frequently occurs in other pathological conditions, e.g., hallux rigidus, in functional impairment of the AJ, and in hindfoot deformities. A much higher prevalence must therefore be assumed.

Pathogenesis, biomechanics, and risk factors

It is useful for systematic purposes to divide the symptom complex into primary and secondary metatarsalgia. Primary metatarsalgia comprises pain of mechanical origin, often as a consequence of metatarsal misalignment or associated with atrophy of the plantar fat pad (e17). Pain caused by other underlying diseases (e.g., Morton neuroma, Köhler disease II, rheumatoid arthritis) is secondary metatarsalgia. Pain in the mid-foot from first ray pathology or disease of the first metatarsophalangeal (MTP) joint is termed transfer metatarsalgia (*Figure 2*).

Knowledge of the biomechanics of the foot and the associated pressure distribution is essential for correct classification of the symptoms. Broadly speaking, in the course of the gait cycle pressure is distributed from heel strike onwards from the center of the heel via the outer edge of the foot between the heads of MT 2 and MT 3 to the great toe. As an amphiarthrosis, the second tarsometatarsal joint displays the least extent of movement and thus offers the least pressure absorption. Therefore loading is particularly high over the head of MT 2 during rollover, often causing symptoms in this area.

Forefoot alignment, which can be assessed in various ways, describes the longitudinal relationship of the metatarsals to one another. The frequently cited metatarsal formula of Maestro et al. is a mathematically calculable ideal longitudinal relationship of the metatarsals (e18, e19). The so-called index minus variant is present when MT 2 is longer than MT 1, the index plus position when MT 1 is longer than MT 2 (e20).

In a frequently cited pedobarography study, Kaipel et al. showed that excessive metatarsal length alone is not associated with elevation of plantar pressure. It is known from studies on resection arthroplasty of the first MTP joint that insufficiency of the first ray—as in hallux valgus—leads to overloading of the central rays

of the metatarsus and thus to severe metatarsalgia (e21, e22) (*eFigure 2*). In claw toe, the pressure on the MT head is elevated by the base of the proximal phalanx and by the tensile force of the tendon (*Figure 2*, *eFigure 2*). One has to assume, therefore, that the etiology of metatarsalgia is multifactorial, with the length and angulation of the metatarsals, the function of the first ray, and pathology of the MTP joints among the key factors.

Diagnostic imaging

The standard projections in foot radiography are the standing dorsoplantar view and the lateral view. They enable evaluation of the frontal alignment and lateral angulation of the metatarsals. The intermetatarsal and hallux valgus angles can be measured and the sesamoid bones assessed. The lateral projection is well suited to analysis of the longitudinal arch, and MTP joint luxations and flexion of the toes can be readily detected.

MRI is valuable for tumor diagnosis, for evaluation of the ligaments, tendons, and plantar plate, for detection of Morton neuroma, in the case of suspected fatigue fractures, and for the diagnosis of aseptic bone necroses. It is particularly helpful in the assessment of cartilage defects, above all when joint-sparing interventions are planned (*eFigure 2*).

Computed tomography finds its role in the diagnosis of posttraumatic situations and deformities, particularly when implants are present and strong artifacts are likely on MRI. Pedobarography is useful to determine the pressure relationships in the foot and for monitoring in the wake of treatment or surgical correction (*Figure 2*).

Interdigital neuroma, bursitis, ganglion, joint effusion, and tendon pathology are all visualized well by sonography.

Conservative treatment

In many cases metatarsalgia can be ameliorated by the use of insoles or specially adapted shoes to modify pressure distribution and improve the joint axes. In a study by Grady et al., 46.9% of 772 patients with hallux rigidus achieved pain relief with no more than the appropriate insoles or modification of their footwear (to facilitate rollover) (e23). Raising of the second and third metatarsal heads by means of an individually moulded insole with a retrocapital cushion or a so-called butterfly roll relieves the pressure in up to 60% of patients (e24, e25). Fixed elevation of the metatarsals, often found in pes equinovarus, can be relieved with cushioning insoles or made-to-measure shoes featuring a soft footbed (e26).

Surgical treatment

Surgical treatment demands precise analysis of the underlying pathology. Particularly in transfer metatarsalgia, correction of the first ray is essential. Owing to the well-known, sometimes intractable complications, the decision to proceed with Weil osteotomy (subcapital shortening osteotomy) should be taken with care.

Key messages

- Plantar fasciitis is viewed as a mechanical reaction to overloading with many contributing factors. Shortening of the calf muscles, long periods of employment in non-sedentary occupations, and malformations of the foot are considered risk factors.
- The causes of metatarsalgia are equally diverse (transfer metatarsalgia from hallux valgus, pes planovalgus, aseptic bony necroses, Morton neuroma, etc.). Solution of the underlying problem is crucial for a successful outcome of treatment.
- The promising conservative treatments for plantar fasciitis include stretching exercises, wearing of insoles, and radiotherapy.
- In more than 90% of cases, chronically recurring plantar fasciitis can be treated successfully by surgical intervention (open or endoscopic plantar fascia release or gastrocnemius release).

A meta-analysis of 1131 Weil osteotomies found that 15% of patients experienced recurrence and 7% developed transfer metatarsalgia. In 36% of cases the operation resulted in floating toe (elevated position of the toe with MTP joint instability), potentially leading to conflict with the footwear and secondary toe deformities (e27). Resection arthroplasty of the MTP joints (according to Brandes, Hueter-Mayo, or Gocht) should not be carried out in patients with good mobility, as severe secondary forefoot deformities and intractable metatarsalgia frequently ensue (e21, e28).

Percutaneous (minimally invasive) techniques are increasingly being used, with good correction, satisfactory cosmetic results, an extremely low rate of wound healing problems, and absence of scar contractions (e29, e30). A number of studies have indicated the functional superiority of distal minimally invasive metatarsal osteotomy (DMMO) or minimally invasive lesser toe corrections (e31–e34). No randomized controlled trials have yet taken place.

A form of displacement osteotomy in which the intact plantar portions of the MT head are swiveled has proved efficacious for the treatment of osteochondral defects following Köhler disease II (*Figure 3*) (e35, e36). Resections frequently lead to secondary instability and deformity of the lesser toes and should be avoided (e37, e38). Finally, one should not forget the procedure according to Hoffmann-Clayton, Lelivre, and Tillmann for resection of the MT heads. As a salvage technique, this operation can lead to satisfactory results in the presence of incapacitating symptoms in patients with low functional requirements (e39).

Conflict of interest statement

The authors declare that no conflict of interest exists.

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► Supplementary material

For eReferences please refer to:
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eFigure 1: Lateral radiography with the patient standing upright (a) and a sagittal MRI section (b) demonstrate a marked yet asymptomatic heel spur (arrow)

eFigure 2: MRI shows bone marrow edema and an osteochondral defect of the dorsal MT 2 head with joint effusion and involvement of the base of the proximal phalanx in Köhler disease II