Extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis and Achilles tendinopathy
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Purpose of review
Extracorporeal shock wave therapy is emerging as a safe and effective treatment for chronic plantar fasciitis and Achilles tendinopathy, although controversy remains. The purpose of this review is to analyze current knowledge relating to this procedure.

Recent findings
Recent basic science studies demonstrated that shock wave therapy can alter neuroreactivity, stimulate growth factor induction, and enhance angiogenesis. Randomized, controlled, clinical trials show that extracorporeal shock wave therapy is safe, therapeutic, and can decrease pain and improve function in treated patients.

Summary
Based on the preponderance of the recent basic science and clinical evidence, extracorporeal shock wave therapy is proposed as another nonoperative treatment for chronic plantar fasciitis and Achilles tendinopathy to be used to avoid surgery.

Keywords
Achilles tendinopathy, extracorporeal shock wave therapy, plantar fasciitis

Introduction
Extracorporeal shock wave therapy (ESWT) has emerged as a popular and effective treatment for many orthopedic conditions including plantar fasciitis, Achilles tendinopathy, lateral epicondylitis, calcific tendinitis of the shoulder, tendinosis of the supraspinatus tendon and patella tendinopathy. While widely used in Europe, in the United States ESWT is most commonly used to treat foot and ankle conditions, usually plantar fasciitis and Achilles tendinopathy.

Numerous clinical trials have shown that ESWT is safe, well tolerated, and yields few side effects [1–8,10,11,12,13]. Significant complications are rare. Many, but not all, multicenter randomized, blinded, and controlled trials have demonstrated that ESWT is more effective than placebo treatment [1–3,6,9].

Some studies, however, have yielded disappointing results [14–16]. Treatment parameters such as the total amount of energy delivered, frequency of shock wave delivery, and method of focusing the shock wave have not been standardized. For that reason it is difficult to compare data from clinical trials.

Treatment algorithms vary from clinic to clinic and from country to country. There are device-specific and disease-specific protocols. Terminology can be confusing. There are 'high energy' single treatments, 'low energy' multiple treatments, and combinations of both. Some devices use imaging to guide shock wave delivery while others rely on 'clinical focusing'. Thus there is a need to synthesize current knowledge relating to this procedure.

Acknowledging these deficiencies, there are sufficient data from numerous clinical and basic science trials that support both a therapeutic benefit and wide safety margin for using ESWT in the treatment of chronic tendinopathies. This review will focus on some of the basic principles, biological effects, and clinical applications of shock wave therapy (SWT) as it relates to plantar fasciitis and Achilles tendinopathy.

Basic principles of extracorporeal shock wave therapy
Shock waves are acoustic sound waves that propagate rapidly as a pressure disturbance through a medium. Shock waves are characterized by a high peak pressure...
(500 bar) with rise times of less than 10 ns, a short life cycle (less than 10 ms), and a broad frequency spectrum (16–20 MHz) [17,18**]. The rapid rise in pressure is followed by periods of pressure dissipation and of negative pressure before gradually returning to ambient pressure [18**].

Extracorporeal shock wave generators are a byproduct of lithotripter technology. These devices use either electro-hydraulic (spark plugs), electromagnetic (coils), or piezoelectric (crystals) methods to generate shock waves [17,18**]. Once generated, the shock waves are then focused by the devices and applied to targeted tissues.

Shock waves entering tissue may be absorbed, reflected, or dissipated depending upon the properties of the tissue [19*]. Shock waves have two basic effects on tissues [19*]. The direct or primary effect is the result of shock waves propagating through and impacting a direct mechanical effect on targeted tissues [19*]. The indirect or secondary effect is the result of cavitation [19*]. Shock wave propagation produces cavitation bubbles in targeted tissues [19*]. The cavitation bubbles expand and collide, thereby imparting additional energy to the treated tissue [19*].

**Physical parameters**

ESWT is traditionally categorized as either low energy (<0.2 mJ/mm²) or high energy (>0.2 mJ/mm²). Low-energy treatment is generally well tolerated, with mild to moderate discomfort and does not require anesthesia. High-energy applications are generally more painful and usually require some type of local or regional anesthesia.

In the United States, the Food and Drug Administration (FDA) has approved three shock wave generators, two high energy and one low energy, for specific musculoskeletal applications. At present, two of the devices are approved for the treatment of plantar fasciitis. A third device has received approval for the treatment of lateral epicondylitis. Clinicians often use shock wave generators ‘off label’ to treat Achilles tendinopathy. Other manufacturers are actively seeking FDA approval for newer devices. There are no randomized trials that have compared the efficacy of the various devices.

ESWT can be applied in single or multiple treatment sessions. Single sessions usually are higher energy and performed in either a surgical center or hospital often with a regional or general anesthetic. Multiple treatment sessions are commonly used in lower energy treatments. These treatments typically occur in a clinic without the use of anesthesia.

The total amount of energy delivered in one session is simply a concentration of total shock wave energy per unit of area. The term ‘total energy flux density’ (recorded in mJ/mm²) represents the total energy applied in a treatment session and is the multiplication of the energy per pulse with the number of pulses given in one session [19*]. It is postulated that a threshold value of energy density has to be exceeded in order to stimulate a biological response [19*].

The number of shocks, frequency of shocks, and energy per shock can all vary. Shock wave frequency is the number of shock waves delivered per second and is measured in hertz. The total number of shocks applied during a treatment session can be manipulated and ranges from 1200 to 4000 depending on protocol. The amount of energy per shock is device specific and also can be varied throughout the procedure.

Shock wave delivery can also vary. Shock waves can be directed in one of several ways. Anatomic focusing refers to application of shock waves to a specific anatomic structure such as the plantar fascia or Achilles tendon [18**]. Image-guided focusing is accomplished using ultrasound or fluoroscopy [18**]. The imaging modality is most often incorporated in the shock wave generator. The images are used to direct the shock waves to specific areas such as an area of soft tissue swelling in the Achilles tendon. Clinical focusing involves directing the shock waves to the areas of maximal pain and tenderness [18**]. Due to the need for patient feedback, clinical focusing is generally performed without local anesthesia.

**Biological effects of extracorporeal shock wave therapy**

When a shock wave encounters a material with a different acoustical impedance, a portion of the energy is absorbed by the tissue, and a portion is reflected [19*]. The ratio of the absorbed to reflected energy varies depending on the specific tissue properties [19*]. Tissues respond differently to SWT. Animal studies have shed some light on this subject.

Studies on rabbit Achilles tendons have shown a dose-dependent effect on treated cells. Rompe et al. [20] showed that there was no irreversible damage to the tendon and adjacent tissues of rabbits treated with energy flux densities up to 0.28 mJ/mm², and that any minor changes completely reversed within 4 weeks of treatment. In contrast, high-energy shock wave application (0.6 mJ/mm²), a dose not used clinically, caused irreversible damage to the tendon and paratenon, including fibrinoid necrosis and an inflammatory reaction in the peri-tendinous tissues.

ESWT is frequently used near articular cartilage. Vaterlein et al. [21], using a rabbit model, reported no changes in the cartilage on macroscopic, radiologic, or histologic examination after administration of 2000 shocks at 1.2 mJ/mm².
It should be noted that such high energy flux densities are not used clinically in the treatment of soft tissue disorders.

ESWT alters neural activity. Ohtori et al. [22] demonstrated that low-energy shock waves produced morphologic changes in rat cutaneous nerve fibers. The number of afferent sensory fibers decreased significantly following shock wave application [22]. Maior et al. [23] used a rabbit model to show that high-energy SWT resulted in a significant decrease in substance P 6 weeks following treatment. Together these studies suggest a neuroinhibitory effect of SWT and help to explain the clinically observed pain reduction in treated patients.

ESWT can result in growth factor proliferation. Chen et al. [24] reported that low-energy SWT promoted healing of collagenase-induced Achilles tendinopathy in rats by inducing transforming growth factor β1 (TGF-β1) and insulin-like growth factor-1 (IGF-I).

ESWT enhances angiogenesis. Wang et al. [25] reported on the effect of low-energy SWT on neovascularization at the tendon–bone junction in rabbits. Tendons treated with low-energy SWT had higher number of neo-vascular fibers and angiogenesis-related markers, including endothelial nitric oxide synthase, vessel endothelial growth factor and proliferating cell nuclear antigen than the untreated controls [25].

**Plantar fasciitis**

Plantar fasciitis is the most common cause of inferior heel pain [11*,26*]. It is estimated that plantar fasciitis afflicts approximately 2 million Americans per year, and it is the most common foot condition seen by dedicated foot and ankle surgeons [26*,27]. The disorder is seen frequently in athletes [7,26*,28,29] but also occurs in sedentary individuals, particularly middle-aged females [26*,28,29].

In runners, plantar fasciitis appears to be associated with overuse, training errors, training on hard surfaces, and improper or excessively worn footwear [7]. In elderly adults, plantar fasciitis is often attributable to poor intrinsic muscle strength and poor force attenuation, secondary to acquired pes planus, and compounded by a decrease in the body’s healing capacity [30]. Men and women are affected equally [26*,30]. Symptoms are bilateral in over 10% of cases [26*].

The pathogenesis remains unclear. It has been hypothesized that excessive stress on the plantar fascia can result in microtears, usually at its origin [26*,31,32]. An inflammatory reaction is incited which then leads to a degenerative process [31]. Biopsies of diseased plantar fascia reveal fibroblastic proliferation and chronic granulomatous tissue [31]. The diseased fascia becomes thickened, from a normal 3.0 mm thickness to as much as 15.0 mm of thickness [31]. Decreased vascularity, loss of normal elasticity, and alterations of nociceptor function may all contribute to the onset and persistence of this condition [28,29].

**Diagnosis**

The diagnosis is usually quite evident. Patients with plantar fasciitis typically complain of pain on the bottom of the heel, particularly with the first steps in the morning and when weight bearing is resumed after prolonged sitting. The pain can be dull, sharp, throbbing or searing. The pain usually persists and often becomes worse with activity.

Physical examination almost always reveals tenderness over the proximal portion of the central fascia, particularly near the insertion on the calcaneal tuberosity. The pain is exacerbated by dorsiflexion of the toes which stretches the plantar fascia.

**Studies**

Diagnostic studies, although generally not necessary, may be helpful when ruling out other conditions.

Radiographs frequently reveal a heel spur on the inferior surface of the calcaneus [33]. The heel spur may be an incidental finding as heel spurs have also been noted in 10–27% of asymptomatic individuals [33].

Plain radiographs may help rule out a calcaneal stress fracture. Should radiographs be normal, a bone scan may also help distinguish plantar fasciitis from a calcaneal stress fracture.

Magnetic resonance imaging (MRI) is particularly helpful at assessing the presence and severity of soft-tissue and bone marrow edema as well as the thickness and signal intensity of the plantar fascia [34]. In one study, 89% of heels with chronic plantar fasciitis had subcutaneous soft-tissue and perifascial edema on T2-weighted images [34]. In nearly all cases, a marked increase in plantar fascial thickness was detected [34].

**Natural history**

The natural history of plantar fasciitis is gradual resolution, but often over an extended period of time. Davis et al. [35] have reported that the vast majority of patients have resolution of the symptoms within 10 months. Others have reported even longer duration of symptoms [1,2,6].

Martin et al. [36] reviewed a large number of reports of nonoperative treatment of plantar fasciitis and showed a wide range of acceptable outcomes ranging from 44% to 82% of patients who obtained complete relief of their
pain. Only 51% of the patients in that study had total resolution of their symptoms.

**Nonoperative treatment**

Acute plantar fasciitis often responds to traditional nonoperative measures [26*,27,29–32]. Evidence of the effectiveness of most of the nonoperative treatment modalities is limited due to the lack of well designed comparative studies. As a result, there is no consensus as to the best method of treatment [26*,27,30,31].

Nonsteroidal antiinflammatory drugs are used for temporary pain relief, but offer no support for resolution of the condition. Randomized placebo-controlled trials have not been conducted to assess their benefit [37,38].

Many physical therapy modalities have been proposed. Support for the use of physical therapy modalities such as ice, heat, massage, creams, ultrasound, and iontophoresis comes from anecdotal data. Results have been mixed [26*].

A wide variety of prefabricated and custom-made orthoses, including heel pads, heel cups, and medial arch supports are used to treat plantar fasciitis. There are no data on the efficacy of these devices as compared with placebo or no treatment, and the available data on their efficacy in comparison with that of other interventions are conflicting or limited [39–42].

Stretching and strengthening of the calf and intrinsic muscles of the foot are also common treatments. These interventions have generally been assessed in combination with others. It is difficult, therefore, to interpret the results of this specific intervention. A recent randomized, controlled trial involving 101 patients showed that heel pain was either eliminated or much improved at 8 weeks in 24 of 46 patients (52%) who undertook stretching the plantar fascia, as compared with eight of 36 patients (22%) who reported such results after participating in a program to stretch the Achilles tendon [43,44*].

The use of night splints, designed to keep the ankle in a neutral position with or without dorsiflexion of the metatarsophalangeal joints during sleep, has been evaluated in three randomized, controlled trials, with conflicting results [45–47].

Corticosteroid injections into the painful fascia generally result in short-term benefit only [48,49]. Steroid injections are often associated with recurrence of symptoms, and the effect is usually temporary [48,49]. Steroid injections may cause infection, fat pad atrophy, and complete plantar fascia rupture [48,49].

In a recent controlled trial botulinum toxin A injection led to superior results compared with placebo [50]. No side effects were noted.

Despite the number and variety of conservative treatments available, approximately 20–30% of those patients treated with traditional measures progress to a chronic condition [51]. Once the condition is chronic, the response to any form of treatment is less predictable [51].

**Surgical management**

Surgical treatment of chronic plantar fasciitis with either open or endoscopic partial plantar fascia release is an option for those who fail to respond to nonoperative measures [52–56]. Some have reported favorable outcomes in more than 75% of patients who underwent surgery [52]. Most surgical studies, however, are uncontrolled, nonrandomized, and use a variety of outcome criteria [52–56]. For this reason, it is difficult to accurately assess the results of surgical intervention.

Schepsis et al. [30] reported that 24 of 27 patients who underwent open plantar fascia release through a medial longitudinal incision were able to return to full activity without significant complaints. Postoperatively, patients were immobilized in a nonweight-bearing cast for 2–3 weeks [30]. Recovery required 6 months.

In an uncontrolled retrospective study of 51 patients undergoing a percutaneous plantar fasciotomy for chronic plantar fasciitis, Weil et al. [52] reported that 83% of treated patients stated that the procedure met or exceeded their expectations. Preoperative visual analog score (VAS) for the entire cohort improved from a mean of 8.7 to a mean of 2.1 at follow-up ranging from 12 to 57 months.

Davies et al. [57] found less favorable results. In his prospective study, 43 patients (47 heels) underwent decompression of the nerve to abductor digiti minimi with partial plantar fascia release for intractable chronic plantar fasciitis. At 31 months, only 20 of 41 patients (49%) were totally satisfied with the outcome [57].

Surgical treatment of plantar fasciitis is not without substantial risk. Open or endoscopic plantar fascia release may be associated with transient swelling of the heel pad, calcaneal fracture, injury of the posterior tibial nerve, complete plantar fascia rupture, prolonged healing, extensive rehabilitation, complete plantar fascia rupture, and permanent alteration of foot biomechanics, with flattening of the longitudinal arch and resultant midtarsal pain [30]. For this reason, patients must be counselled regarding the potential benefits and limitations of surgery.
Plantar fasciitis and extracorporeal shock wave therapy

The literature is replete with studies regarding the efficacy of ESWT as a treatment for chronic plantar fasciitis. The following is a summary of some of the most important clinical trials.

Low-energy shock wave therapy

Rompe et al. [5] were the first to perform a controlled study to explore the pain-alleviating effect of low-energy SWT in the chronic painful heel. Thirty patients received 3 × 1000 impulses of 0.06 mJ/mm² at weekly intervals or placebo, without local anesthesia. Twelve weeks after the last treatment, study patients experienced a significant alleviation of pain and improvement in function when compared with controls [5].

The same authors [7] evaluated the outcome of shock wave treatment of chronic plantar fasciitis in runners. Forty-five running athletes were either assigned to a treatment group that received 3 × 2100 impulses of 0.09 mJ/mm² or placebo, without local anesthesia. At 24 weeks, 60% versus 27% of patients reported more than 50% reduction in pain on first walking in the morning [7].

Weil et al. [52] reported their results using low-energy radial SWT. Two hundred and forty-two randomized patients received active treatment with 3 × 2000 pulses at weekly intervals or sham, without local anesthesia. Fifty-seven percent versus 40% achieved successful alleviation of their morning pain.

Consentino et al. [4] reported on 60 patients undergoing regular treatment with six sessions of 1200 low-energy impulses at weekly intervals or placebo, without local anesthesia. A significant decrease in VAS was only seen in the treatment group at 12 weeks [4].

Malay et al. [10*] compared the outcomes of 172 participants treated with a newer SWT device with those treated with placebo. SWT with 3800 shocks or placebo was administered without local anesthesia. The amount of energy delivered was not specified in this study. At 12 weeks, 45% versus 20% of patients reported a decrease in pain from baseline of 50%.

The studies from Rompe et al. [7] and from Consentino et al. [4] used image guidance, while Rompe et al. [5], Weil et al. [52] and Malay et al. [10*] relied on clinical focusing to the point of maximum tenderness. Image guidance was used to direct the shock wave to the tip of the calcaneal spur, followed by clinical focusing of the shock wave to the area of maximal pain.

Of note, in each of the trials described above, the repetitive treatments were administered at weekly intervals, and none used any form of LA. Follow-up was at least 12 weeks after SWT.

Speed et al. [16] changed the therapeutic regimen significantly by administering SWT at monthly intervals and by assessing follow-up 4 weeks after treatment. Eighty-eight adults with chronic plantar fasciitis received either 3 × 1500 impulses of 0.12 mJ/mm², or sham therapy without local anesthesia, at monthly intervals. At 4 weeks from treatment, 37% and 24% of the groups showed a 50% improvement from baseline with respect to pain (not significant).

Haake et al. [15] also deviated from the therapeutic regimen described above. Two hundred and seventy-two patients with chronic plantar fasciitis were allocated to receive SWT with 3 × 4000 impulses of 0.08 mJ/mm² under local anesthesia or placebo SWT under local anesthesia at weekly intervals. The success rate 12 weeks after intervention was 34% in the SWT group, and 30% in the placebo group (not significant).

Shock wave application under local anesthesia

Label et al. [58] was the first to focus on a possible interference of local anesthesia on the outcome after SWT. Sixty patients with chronic plantar fasciitis were enrolled in a triple-arm pilot trial. Patients received either active SWT without local anesthesia (3 × 1500 shocks of 0.09 mJ/mm², group A), SWT with local anesthesia (3 × 1500 shocks of 0.18 mJ/mm², group B) or SWT with local anesthesia (3 × 1500 shocks of 0.09 mJ/mm², group C) at weekly intervals. At 6 weeks, a reduction of pain of at least 50% was achieved in 60% of group A, in 36% of group B and in 30% of group C. The authors concluded that local anesthesia significantly influenced the clinical results after low-energy ESWT in a negative way.

In another study, 86 patients with chronic plantar fasciitis were randomly assigned to receive either 3 × 2000 pulses of 0.09 mJ/mm² without local anesthesia, at weekly intervals, or identical SWT with local anesthesia [8]. At 12 weeks, significantly more patients of group I achieved 50% reduction in pain compared with group II (67% versus 22%).

Low number of shock waves

In 1998, Kirschek et al. [59] enrolled 50 chronic plantar fasciitis patients, the first group receiving 3 × 500 impulses and the second group 3 × 100 impulses of 0.08 mJ/mm², at weekly intervals, under fluoroscopic control. The authors described a significantly better result after the treatment with 3 × 500 impulses at 12 weeks.

Rompe et al. [6] reported that at 24 weeks, of 112 patients with chronic plantar fasciitis allocated to either 3 × 1000 impulses with local anesthesia, 40% versus 28% of patients reported a decrease in pain by at least 50%.
waves to two very different areas. A further report was considered a reanalysis of the previously published trial with substantially different sample sizes [1, 2]. While the results appeared similar, the authors now claimed a significant difference in the mean score for the subjective self-assessment of pain at 12 weeks, favoring the active treatment group. Twelve weeks after treatment, 47% of the actively treated patients had a completely successful result compared with 30% of the placebo-treated patients.

Corticosteroid injection
Porter and Shadbolt [60] reported a comparison of the efficacy of low-energy SWT and intrallesional corticosteroid injection for the treatment of plantar fasciitis present for at least 6 weeks. One hundred and thirty-two patients were enrolled; 19 nonrandomized patients acted as a surrogate control group. The patients were randomly allocated to either SWT with 3 × 1000 shocks of 0.08 mJ/mm² without local anesthesia at weekly intervals or a single corticosteroid injection. Nineteen nonrandomized patients performed a standardized stretching program only.

At 12 weeks, the tenderness values at the plantar fascia insertion were significantly higher after the corticosteroid injection than both after SWT and in the controls. The VAS, however, was significantly lower after the corticosteroid injection than both after SWT and in controls.

High-energy shock wave therapy
Ogden et al. [1] performed a placebo-controlled trial of a single SWT with 1500 shocks of 0.22 mJ/mm², using ankle-block anesthetic, in 302 patients with chronic plantar fasciitis. At 12 weeks, 62% versus 43% of the patients had a minimum 50% improvement over baseline in investigator assessment of pain. Outcomes of three other criteria, including the subjective self-assessment of pain, also favored active treatment, although none was statistically significant.

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Theodore et al. [3] reported their experience using a different high energy shock wave generating device. In a multicenter placebo-controlled study consisting of 150 patients with chronic plantar fasciitis, the active group was treated with a single application of 3800 pulses of 0.36 mJ/mm² whereas a similar number of patients received a sham treatment. All procedures were performed using regional anesthesia. Ultrasound guidance was used. At 12 weeks, 62% of the patients in the active group reported good or excellent outcome, and 40% in the placebo group (P < 0.05).

Using the same device, Kudo et al. [9**] treated 114 patients with chronic plantar fasciitis. Treatment consisted of 3800 high-energy shock waves of 0.36 mJ/mm² in a single session under regional anesthesia versus placebo treatment. At 12 weeks 47% versus 23% of patients reported an improvement of over 60% from baseline in VAS scores for pain during the first few minutes of

Buchbinder et al. [14] enrolled 166 acute and chronic patients in a trial to determine whether ultrasound-guided SWT reduced pain in patients with plantar fasciitis. Patients were randomly assigned to receive either ultrasound-guided SWT with 3 × 2000 or 3 × 2500 shocks of 0.02–0.33 mJ/mm², given weekly for 3 weeks, or 3 × 100 shocks of 0.02 mJ/mm². At 12 weeks, there were significant improvements in overall pain in both the active and the placebo groups, with no statistically significant differences in the degree of improvement between treatment groups for any measured outcomes.

The Buchbinder study has been the subject of much discussion. Although similar to the Rompe study in regards to the amount and energy of shock waves delivered and the time between treatments, there are also many important differences which may account for the negative results.

The first difference was in the inclusion criteria. Although the patients in the two trials also had similar mean duration of symptoms, the study by Buchbinder et al. [14] included patients experiencing symptoms for as little as 6 weeks, whereas Rompe et al.’s [6] minimum was 6 months. Further, the trial by Buchbinder et al. [14] included patients with plantar heel pain and ultrasonic evidence of thickening of the plantar fascia. In the trial by Rompe et al. [6], the criteria were limited to pain at the insertion of the plantar fascia on the medial calcaneal tuberosity. These patient populations were not necessarily the same.

Second, although both studies used image guidance for the localization technique, the shock waves were focused on different areas [6, 14]. Rompe et al. focused their shock waves on the tip of the calcaneal spur followed by clinical focusing, while Buchbinder et al. used ultrasound to focus on the thickest part of the plantar fascia. This difference may be several millimetres, resulting in delivery of shock waves to two very different areas.

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walking; 43% versus 30% reported a good or excellent outcome ($P < 0.05$).

**Achilles tendinopathy**

Achilles tendon injuries occur frequently in runners and jumping athletes and are also common in the general population [61–70,71*,72]. The condition is more common in older athletes [68]. The precise etiology and natural history of these injuries remain unknown [67,68,70,71*,72].

Intrinsic risk factors include hyperpronation, varus deformity of the forefoot, leg length discrepancy, and limited mobility of the subtalar joint [65–67,70]. Extrinsic risk factors include excessive mechanical overload and training errors such as increased interval training, excessive hill training, and increased mileage [64–67,69,70]. Other risk factors include poor technique, fatigue, and advanced age [63,65–67,69].

Maffulli et al. [73,74] have popularized the term ‘Achilles tendinopathy’ to describe the triad of tendon pain, swelling, and impaired performance. From a functional perspective it is helpful to classify Achilles tendinopathy as insertional – when it occurs at the bone–tendon junction, or noninsertional – when it occurs more proximally [67,75]. Insertional tendinopathy tends to occur in more active individuals whereas noninsertional tendon injury tends to occur in older, less athletic, and overweight individuals [67,75].

**Diagnosis**

In the acute phase, patients with noninsertional Achilles tendinopathy usually complain of pain, swelling, warmth, and a ‘squeaking’ sensation over the distal aspects of the tendon. Running, stair climbing, and activities requiring push-off aggravate the condition. In the more chronic phase of Achilles tendinopathy, crepitance, and warmth diminish, but pain becomes more constant. Physical examination usually reveals fusiform tendon swelling and tenderness 3–5 cm proximal to the tendon’s insertion.

Patients with insertional Achilles tendinopathy complain of posterior heel pain and swelling located at the bone–tendon junction. The pain is worse after activity and may also become constant. Physical examination reveals point tenderness at the Achilles tendon insertion. The pain is aggravated with passive dorsiflexion. Passive motion is often decreased when compared with the unaffected heel [70].

**Studies**

Plain radiographs are generally helpful. They can reveal prominence of the posterior–superior aspects of the calcaneus, ossification or calcification in the tendon body, and posterior calcaneal osteophytes [67–68]. Ultrasound and MRI imaging are frequently used to evaluate tendon morphology [67,68]. Imaging can reveal pathologic changes in the tendon itself as well as in the peritenon and retrocalcaneal bursa.

**Natural history**

Most instances of acute cases of Achilles tendinopathy resolve gradually with nonoperative care. Just as with plantar fasciitis, however, there is a subset of patients who do not respond to conservative therapies.

In an 8-year follow-up study, nonoperative treatment was unsuccessful in 29% of a cohort of 83 patients [76]. Patients who do not respond to 6 months of nonoperative treatment are generally considered surgical candidates [67,68].

**Nonoperative treatment**

Currently there is no consensus as to the best method to treat Achilles tendinopathy. Traditional nonoperative treatment of Achilles tendinopathy consists of relative rest, activity modification, antiinflammatory medications, various forms of physical therapy, heel lifts, taping, heavy-load eccentric calf muscle training, and orthotics [61–70,72]. Unfortunately, there are few data to support the use of many of these therapeutic measures [67,71*].

In the majority of cases, nonoperative measures are effective [61–70,72].

**Surgical treatment**

Surgery is reserved for chronic cases. Options include open excision of the degenerative tendon with paratenon stripping and creation of small, multiple longitudinal tenotomies, open excision of degenerative tendon without paratenon stripping, endoscopic debridement, or creation of multiple percutaneous longitudinal tenotomies [67–70,77,78]. Success rates vary from series to series [77–79] and the rate of complications, particularly delayed wound healing, can be high [79].

**Extracorporeal shock wave therapy and Achilles tendinopathy**

Pilot studies investigating the effects of ESWT on Achilles tendinopathy have been promising. Lohrer et al. [80] reported significant pain reduction and increased functionality in patients with Achilles tendinopathy who were treated with radial SWT. There was no control group, however.

Perlick et al. [81] compared ESWT with surgery as a treatment for chronic Achilles tendinopathy. At 1-year follow-up, there was a statistically significant reduction in
pain using a VAS in both groups: from 73 to 38 and from 70 to 28 in the ESWT and operative group, respectively.

In a small, randomized, double-blinded, placebo-controlled trial consisting of 39 patients, Peers [82] reported his experience using low-energy ESWT for the treatment of patients with chronic Achilles tendinopathy. At 12-week follow-up, the 20 treated patients had significantly improved VASs when compared with an untreated control group. A 77% success rate was reported.

Furia [13] evaluated the effects of high-energy ESWT on a consecutive series of patients with chronic Achilles tendinopathy that had not responded to nonoperative management. Thirty-five patients with chronic insertional Achilles tendinopathy were treated with a single dose of high-energy ESWT (ESWT group, 3000 shocks, 0.21 mJ/mm², total energy density of 604 mJ/mm²). Thirty-three patients with chronic insertional Achilles tendinopathy were not treated with ESWT, but instead were treated with additional forms of nonoperative therapy (control group). All ESWT procedures were performed using either a local anesthesia field block (12 patients) or an anesthesia other than local (23 patients). Evaluation was by change in VAS and by determination of the Roles and Maudsley score.

One month, 3 months, and 12 months following treatment, the mean VASs for the control and ESWT groups were 8.2 and 4.2 (P < 0.001), 7.2 and 2.9 (P < 0.001), and 7.0 and 2.8 (P < 0.001), respectively. Chi-square analysis revealed that the number of patients with excellent or good Roles and Maudsley scores (i.e. successful results) 12 months following treatment was statistically greater in the ESWT group compared with the control group (P > 0.0002). Overall, the percentage of excellent or good results using the Roles and Maudsley score at 12 months following procedure for the ESWT and control groups were 82.9% and 39.4%, respectively.

Of note, analysis of variance (ANOVA) testing at 12 months following treatment revealed that the mean improvement in VAS score for the local anesthesia sub-group was significantly less than the corresponding gain in the nonlocal anesthesia subgroup (F = 16.77 versus 53.95, P < .001). Although patients in both the subgroups improved, those patients treated without local anesthesia improved to a greater degree. There were no significant complications and no patient required additional SWT.

The author concluded that high-energy ESWT is a safe and effective procedure that can be used to treat patients with chronic insertional Achilles tendinopathy. The positive treatment effect may be compromised by application of a local anesthesia to the painful area prior to ESWT.

In a recent randomized, controlled trial, Rompe et al. [83] compared the effectiveness of three management strategies for the treatment of noninsertional Achilles tendinopathy. Group one was treated with eccentric loading exercises, group two was treated with repetitive low-energy SWT, and group 3 was treated with a ‘wait-and-see’ approach. All of the 75 enrolled patients had received unsuccessful management with traditional nonoperative methods for a minimum of 3 months.

At 4 months from baseline, the VASs increased in all groups, from 51 to 76 points in group 1, from 50 to 70 points in group 2, and from 48 to 55 points in group 3. Pain rating decreased in all groups, from 7 to 3 points in group 1, from 7 to 4 points in group 2, and from 8 to 6 points in group 3. For all outcome measures, groups 1 and 2 did not differ significantly. For all outcome measures, groups 1 and 2 showed significantly better results than group 3. The authors concluded that the wait-and-see strategy was ineffective for the management of chronic tendinopathy of the main body of the Achilles tendon. They recommend either eccentric loading exercise, SWT, or a combination of both for patients with chronic tendinopathy of the main body of the Achilles tendon.

Conclusion

ESWT is an emerging technology. The multiple variables associated with this therapy, that is, different modes of delivery of the shock waves – single treatment versus multiple treatments, low energy versus high energy, the method of focusing, the total amount of energy delivered, and the method of generating the shock waves – electrohydraulic versus electromagnetic, can all influence the outcome of the treatment. The heterogeneity of the treatment parameters also makes it difficult to compare trials. That said, there are now many randomized, controlled trials published in the peer-reviewed literature that support the use of ESWT in the treatment of chronic plantar fasciitis and Achilles tendinopathy.

ESWT has several advantages over other forms of treatment of plantar fasciitis and Achilles tendinopathy. Relief from pain can be recognized with a single or perhaps two or three sessions compared with traditional nonoperative therapies that require multiple applications and for which clear benefits have not been established. ESWT is safe, noninvasive and associated with only minor, transient side effects. Compared with surgery, recovery from SWT generally is less painful and occurs without significant morbidity. SWT circumvents the need for immobilization and restricted weight bearing and generally has a relatively short recovery time. Lost time from work is usually minimal and often as little as one day.
ESWT is proposed as another nonoperative treatment of chronic plantar fasciitis and Achilles tendinopathy to be used to avoid surgery. Further prospective work is underway to better define this emerging technology.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

• of special interest

•• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 190).


Excellent, randomized, placebo-controlled confirmatory trial in which a standardized high-energy protocol, one that had been used in prior studies, was shown to be an effective treatment for patients with chronic plantar fasciitis. This trial provides further level I evidence in support of ESWT as a treatment for chronic plantar fasciitis.


Another large, well-designed, randomized, placebo-controlled trial that supports the use of ESWT as a treatment for chronic plantar fasciitis. This trial provides further level I evidence that favors the use of ESWT in the treatment of chronic plantar fasciitis.


In this smaller clinical trial, high-energy ESWT was shown to be an effective treatment for a broad spectrum of patients with chronic plantar fasciitis. The results indicated that the high-energy, single treatment protocol can be safely performed without significant complications in the community setting.


This is a recent review of the efficacy and controversy associated with ESWT as a treatment for multiple chronic tendinopathies including plantar fasciitis, Achilles tendinopathy, lateral epicondylitis, and calcific tendinitis of the shoulder.


This is a good review of the technical principles of ESWT and summarizes some of the current hypotheses regarding the biological effects of SWT on musculoskeletal tissues.


In this comprehensive review, the authors highlight the clinical presentation of plantar fasciitis and discuss the diagnosis and effectiveness of the various treatment options for plantar fasciitis.


34 Zhu F, Johnson JE, Bae K. Chronic plantar fasciitis: acute changes in the heel treatment options for plantar fasciitis. Foot Ankle Int 1999; 20:214–221.


In this prospective clinical trial, with long-term follow-up, the authors report on the effectiveness of a new stretching protocol as a treatment for patients with chronic plantar fasciitis.


