Medical Policy Manual

**Topic:** Extracorporeal Shock Wave Treatment for Plantar Fasciitis and Other Musculoskeletal Conditions  
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**Section:** Medicine  
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**Effective Date:** January 1, 2017

**IMPORTANT REMINDER**

Medical Policies are developed to provide guidance for members and providers regarding coverage in accordance with contract terms. Benefit determinations are based in all cases on the applicable contract language. To the extent there may be any conflict between the Medical Policy and contract language, the contract language takes precedence.

PLEASE NOTE: Contracts exclude from coverage, among other things, services or procedures that are considered investigational or cosmetic. Providers may bill members for services or procedures that are considered investigational or cosmetic. Providers are encouraged to inform members before rendering such services that the members are likely to be financially responsible for the cost of these services.

**DESCRIPTION**

**Extracorporeal Shock Wave Treatment (ESWT)**

Extracorporeal shock wave treatment (ESWT), also known as orthotripsy, has been available since the early 1980s for the treatment of renal stones, and has been widely investigated for the treatment of biliary stones. Shock waves create a transient pressure disturbance, which disrupts solid structures, breaking them into smaller fragments, allowing spontaneous passage and/or removal of stones. The mechanism by which ESWT might have an effect on musculoskeletal conditions is not well defined.

Chronic musculoskeletal conditions, such as tendinitis, can be associated with a substantial degree of scarring and calcium deposition. Calcium deposits may restrict motion and encroach on other structures such as nerves and blood vessels, causing pain and decreased function. One hypothesis is that disruption of these calcific deposits by shock waves may loosen adjacent structures and promote resorption of calcium, thereby decreasing pain and improving function. Other functions are also thought to be involved. Physical stimuli are known to activate endogenous pain control systems, and activation by shock waves may "reset" the endogenous pain receptors. Damage to endothelial tissue from ESWT may result in increased vessel wall permeability, causing increased diffusion of cytokines, which may in turn promote healing. Microtrauma induced by ESWT may promote angiogenesis and thus aid in healing.
Finally, shock waves have been shown to stimulate osteogenesis and promote callous formation in animals, which is the rationale for ESWT in delayed union or non-union of bone fractures.

Both high-dose and low-dose protocols have been investigated. A high-dose protocol consists of a single treatment of high energy shock waves (1300mJ/mm²). This painful procedure requires anesthesia. A low-dose protocol consists of multiple treatments, spaced one week to one month apart, in which a lower dose of shock waves is applied (1405mJ/mm² over three sessions). This protocol does not require anesthesia.

**Plantar Fasciitis**

Plantar fasciitis is a very common ailment characterized by deep pain in the plantar aspect of the heel, particularly on arising from bed. While the pain may subside with activity, in some patients the pain may persist, interrupting activities of daily living. On physical examination, firm pressure will elicit a tender spot over the medial tubercle of the calcaneus. The exact etiology of plantar fasciitis is unclear, although repetitive injury is suspected. Heel spurs are a common associated finding, although it has never been proven that heel spurs are the cause of the pain. It should be noted that asymptomatic heel spurs can be found in up to 10% of the population. Most cases of plantar fasciitis are treated with conservative therapy, including rest or minimization or running and jumping, heel cups, and nonsteroidal-anti-inflammatory drugs. Local steroid injection may also be used. Improvement may take up to 1 year in some cases.

Conservative therapy of plantar fasciitis is successful in the vast majority of cases. Rest or minimization of running or jumping is the cornerstone of therapy. Heel cups are sometimes helpful in alleviating symptoms, presumably by padding the heel and absorbing the impact of walking. Nonsteroidal anti-inflammatory drugs are also helpful in acute cases. If the above measures are ineffective, a local injection of steroids may be effective. Improvement is frustratingly slow and gradual, taking up to a year in some cases. For refractory cases, either open or endoscopic plantar fasciotomy may be considered.

**Tendinopathies**

**Tendinitis of the Shoulder**

*Tendinitis of the shoulder* results from strain of the shoulder girdle muscles, most commonly the muscles of the rotator cuff. These small muscles control rotation of the shoulder and are prone to injury and inflammation due to their location and relative weakness.

*Calcific tendinitis* refers to a condition in which clinical signs and symptoms of tendinitis are accompanied by calcium deposition at the site of the affected tendon. This most commonly occurs at the origin of the supraspinatus muscle but may also involve other muscles of the rotator cuff. The cause of calcium deposition is not well understood, and there is not a clear correlation between clinical symptoms and the presence or extent of calcific deposits. Many patients with chronic tendinitis do not have calcium deposition, and less than half of patients with calcific deposition on x-ray exhibit clinical symptoms.

Initial therapy consists of rest, anti-inflammatory medications, physical therapy, and/or local corticosteroid injections. Response to conservative therapy varies, but it is common for shoulder tendinitis to become chronic, especially when the muscles of the rotator cuff are involved. When conservative treatment fails, a number of invasive techniques are available for both calcific and non-
calcific tendinitis of the shoulder. For example, needle irrigation can be performed for calcific tendinitis, during which calcium deposits are localized and disrupted by needling under fluoroscopic guidance. Following disruption, irrigation and aspiration removes loose calcium particles. Approximately 10% of patients with chronic shoulder tendinitis undergo surgery, usually performed arthroscopically.

**Tendinitis of the Elbow**

*Lateral epicondylitis* is the most common form of tendinitis of the elbow, and results in lateral elbow pain and functional limitations. The disorder is caused by overuse or injury of the tendons that attach the arm muscles to the elbow, such as commonly occurs from playing tennis (“tennis elbow”). However, only a minority of cases are caused by playing tennis; the majority occur from other activities that involve repetitive extension of the wrist. Overuse of the extensor muscles lead to microtears at their insertion point, which incites an inflammatory response. Repetitive cycles of injury and inflammation lead to tendinosis, degeneration of the tendon structures, and disorganized healing.

The diagnosis of lateral epicondylitis is made by characteristic pain and tenderness at the lateral aspect of the elbow, in conjunction with typical activities or injury that accompany this condition. Radiologic imaging is not necessary for diagnosis, but may be useful in ruling out other causes of lateral elbow pain, such as fracture, dislocation, degenerative joint disease, and other bony or soft tissue pathologies. Imaging is usually normal in lateral epicondylitis, although occasionally calcium deposition can be seen.

Conservative treatment consists of rest, activity modification, anti-inflammatory medications, and/or physical therapy. Corticosteroid injections and orthotic devices can also be tried as adjuncts to conservative measures. A number of surgical treatments are available for patients who do not respond to conservative treatment; approximately 5%–10% of patients with tendinitis of the elbow require surgery. Surgery may be performed as open or laparoscopic procedures. The general approach is to debride any degenerative or nonviable tissue and to repair tears or other structural abnormalities.

**Fracture Nonunion and Delayed Union**

The definition of a fracture nonunion has remained controversial, particularly in the duration of time required to define a condition of nonunion. Complicated variables are present in fractures, i.e., degree of soft tissue damage, alignment of the bone fragments, vascularity, and quality of the underlying bone stock. The time period has been variously described as lack of visible signs of healing within 3 months, 6 months, or 9 months. A substantial source for the disagreement regarding the clinical definition of nonunion stems from the use of heterogeneous study populations, which limit comparisons between studies. The nonunion fracture can be further defined as atrophic, in which no callus formation occurs, or hypertrophic, with callus formation at both sides of the fracture, but without fusion. Delayed union refers to a decelerating bone healing process, as identified in serial x-rays, together with a lack of clinical and radiologic evidence of union, bony continuity, or bone reaction at the fracture site for no less than 3 months from the index injury or the most recent intervention. (In contrast, nonunion serial x-rays show no evidence of healing.) When grouped together, delayed union and nonunion are sometimes referred to as ununited fractures.

**Other Musculoskeletal and Neurologic Conditions**
ESWT has been investigated for a variety of other musculoskeletal conditions, including medial tibial stress syndrome, osteonecrosis (avascular necrosis) of the femoral head, coccodynia, and painful stump neuromas.

Spasticity refers to a motor disorder characterized by increased velocity-dependent stretch reflexes. It is one characteristic of upper motor neuron dysfunction, which may be due to a variety of pathologies.

**Regulatory Status**

ESWT devices approved by the U.S. Food and Drug Administration (FDA) include the following:

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Type</th>
<th>FDA Approved Indication(s)</th>
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<tbody>
<tr>
<td>OssaTron® device (HealthTronics)</td>
<td>High-dose - Electrohydraulic delivery system</td>
<td>Chronic proximal plantar fasciitis for patients with symptoms of plantar fasciitis for 6 months or more that has failed to respond to conservative management. Chronic lateral epicondylitis (tennis elbow) that has failed to respond to conservative treatment.</td>
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<tr>
<td>Epos™ Ultra (Dornier)</td>
<td>High-dose - Electromagnetic delivery system</td>
<td>Treatment of chronic plantar fasciitis for patients with symptoms of plantar fasciitis for 6 months or more and a history of unsuccessful conservative therapy.</td>
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<tr>
<td>SONOCUR® Basic (Seimens)</td>
<td>Low-dose - Electromagnetic delivery system</td>
<td>Treatment of chronic lateral epicondylitis (commonly referred to as tennis elbow) for patients with symptoms of chronic lateral epicondylitis unresponsive to conservative treatments for more than 6 months.</td>
</tr>
<tr>
<td>Orthospec™ Extracorporeal Shock Wave Therapy Device (Medispec Ltd.,)</td>
<td>High-energy – Electrohydraulic/Spark Gap</td>
<td>Treatment of chronic proximal plantar fasciitis with or without heel spur in patients 18 years of age or older who have had symptoms for 6 months or more and a history of unsuccessful conservative therapies to relieve heel pain.</td>
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<tr>
<td>Orbasone™ Pain Relief System (Orthometrix)</td>
<td>High-energy – sonic wave</td>
<td>Treatment of chronic proximal plantar fasciitis in patients 18 years of age or older that has failed to respond to conservative therapy. Chronic proximal plantar fasciitis is defined as heel pain in the area of the insertion of the plantar fascia on the medial calcaneal tuberosity that has persisted for 6 months or more.</td>
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<td>Device Name</td>
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<td>Dolorclast® (EMS - Electro Medical Systems)</td>
<td>Radial ESWT (rESWT)</td>
<td>Radial ESWT is generated ballistically by accelerating a bullet to hit an applicator, which transforms the kinetic energy into radially expanding shock waves. Other types of ESWT produce focused shock waves that show deeper tissue penetration with significantly higher energies concentrated to a small focus. Radial ESWT is described as an alternative to focused ESWT and is said to address larger treatment areas, thus providing potential advantages in superficial applications like tendinopathies.</td>
</tr>
<tr>
<td>Duolith® SD1 Shock Wave Therapy Device (Storz Medical AG)</td>
<td>Electromagnetic delivery</td>
<td>Treatment of chronic proximal plantar fasciitis in patients 18 years of age or older with a history of failed alternative conservative therapies for at least 6 months.</td>
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**MEDICAL POLICY CRITERIA**

Extracorporeal shock wave treatment, using either a high- or low-dose protocol, is considered **investigational** for all musculoskeletal indications, including but not limited to:

A. Acute fracture
B. Avascular necrosis (osteonecrosis) of the femoral head
C. Delayed union and nonunion of fractures
D. Plantar fasciitis
E. Spasticity
F. Tendinopathies, including but not limited to:
   1. Achilles tendinopathy (including Achilles tendinitis)
   2. Medial tibial stress syndrome (MTSS) (“shin splints”)
   3. Tendinitis of the elbow (including lateral epicondylitis, also known as tennis elbow)
   4. Tendinitis of the knee
   5. Tendinitis of the shoulder (including calcific tendinitis of the shoulder)
SCIENTIFIC EVIDENCE

The most clinically relevant outcomes of ESWT used for musculoskeletal conditions are improvements in pain and/or function. Both of these outcomes can be influenced by nonspecific effects, placebo response, natural history of the disease, and regression to the mean; therefore, they need to be evaluated in randomized, controlled trials that maintain satisfactory blinding of the treatment assignment. Both the 2003 and 2004 TEC Assessments focused on double-blind studies, as the observed placebo effect in double-blinded trials of ESWT for plantar fasciitis was substantially greater than in single-blind trials. Pain outcomes require quantifiable pre- and post-treatment measures, which are most commonly measured with a visual analogue scale (VAS). Collectively, the pain measurement literature cautions against using only statistical significance of difference in mean change in scores to determine clinical significance. More meaningful to patients and clinicians is the correlation of improvement in pain scores with improvement in function and quality of life. Thus, quantifiable pre- and post-treatment measures of functional status are also necessary. Although there is a lack of validated instruments for many indications, in some cases the SF12 and SF36 (instruments for measuring health status and outcomes from the patient’s point of view) may be employed for this purpose. Also used in some studies were the Roles and Maudsley score, the Maryland Foot score, and the American Orthopedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot scale.

Plantar Fasciitis

Systematic Reviews

In 2014, Yin and colleagues conducted a systematic review and meta-analysis, that included 7 randomized or quasi-randomized studies (n=550) regarding the efficacy of ESWT for chronic recalcitrant plantar fasciitis.[1] For the primary outcome of treatment success rate, which was defined differently across the included studies, pooled analysis of the 5 trials (N=448 subjects) that evaluated low-intensity ESWT showed that ESWT was more likely than control to lead to treatment success (pooled risk ratio [RR] 1.69; 95% CI 1.37 to 2.07; P<0.001). In pooled analysis of the 2 trials (N=105 subjects) that evaluated high-intensity ESWT, there was no difference between ESWT and control in treatment success. A strength of this analysis is restricting the population to patients with at least 6 months of symptoms, since this is a clinical population that is more difficult to treat and less likely to respond to interventions. However, a weakness of this study is the heterogeneity in the definition of “treatment success”, which makes interpreting the pooled analysis challenging.

A 2004 TEC Assessment on ESWT for the treatment of chronic plantar fasciitis[2] focused on five randomized, double-blind studies reporting on 878 patients, all of which were judged to be of high quality based on specific criteria.[3-9] These studies reported mixed results. In the HealthTronics Surgical Services, Inc/Ogden et al.[3,4] trial with 293 patients both ESWT and sham treatment groups demonstrated improvement at 12 weeks posttreatment, with the ESWT group reporting statistically significant improvement in pain on first walking in the morning and improvement in the investigator assessment of pain, but the percent of patients who had a 50% improvement in pain was not statistically significant (60% vs. 48%, p=0.13). The Buchbinder et al. trial with 166 patients also reported improvement in both groups, but no significant difference at 6 and 12 weeks posttreatment.[5] Similar results with no difference between groups were reported for a trial by Haake et al. with 272 patients and 1 year of follow-up.[6] A trial with 45 runners found that the ESWT group had greater improvement on self-assessment of morning pain compared to the placebo group at six months follow-up, but treatment success measures did not significantly differ.[7] Similarly, the study by Theodore et al/Dornier Medical
Systems, Inc. with 150 patients reported improvement in pain measures, but not overall success rate with ESWT.[8,9] It should be noted that although the above studies employed differing treatment protocols (high-dose versus low-dose), there are no controlled clinical trials that test the relative efficacy of differing techniques for shock wave dosage or delivery. Specifically, the effect of different dosage protocols on physiologic measures, magnitude of treatment effect, and/or adverse effects has not been determined.

The evidence included in the 2004 TEC Assessment of ESWT for the treatment of chronic plantar fasciitis demonstrated a statistically significant difference in morning pain measured on a 0–10 VAS score. However, the clinical significance of the change was uncertain as the absolute value and effect size were small. The number needed to treat (NNT) to achieve 50%–60% reduction in morning pain was 7 (95% CI: 4–15), derived from the three studies of high-energy ESWT. Improvements in pain measures were not clearly associated with improvements in function. Effect size for improvement in pain with activity was non-significant, based on reporting for 81% of patients in all studies and 73% of patients in high-energy ESWT studies. Success in improvement in Roles and Maudsley score was reported for fewer than half the patients and although statistically significant, confidence intervals were wide. Where reported, improvement in morning pain was not accompanied by significant difference in quality-of-life measurement (SF-12, physical and mental scales) or use in pain medication. Therefore, TEC concluded that the technology assessment criteria were not met.

Randomized Controlled Trials (RCTs)

In 2015, Gollwitzer et al reported results of a sham-controlled RCT, with patients and outcome assessments blinded, evaluating ESWT for plantar fasciitis present for at least 6 months and refractory to at least 2 nonpharmacologic and 2 pharmacologic treatments.[10] A total of 250 subjects were enrolled and treated (126 in the ESWT group, 124 in the placebo group). For the study’s primary outcome, overall reduction of heel pain, measured by percentage change of the VAS composite score 12 weeks after the last intervention compared with baseline, the median decrease was greater for the ESWT group (-69.2%) than for the placebo group (-34.5%; Mann-Whitney effect size, 0.6026; p=0.003). Secondary outcomes included success rates (defined as decrease of heel pain of at least 60% from baseline for at least 2 of 3 heel pain VAS measurements) for a variety of heel pain measurements. Secondary outcomes generally favored ESWT group. For example, 54.4% of ESWT patients had reduced overall heel pain compared with 37.2% of placebo patients (odds ratio [OR], 2.015; p=0.004, 1-sided). Most patients reported satisfaction with the procedure. Strengths of this study included intention-to-treat analysis, use of validated outcome measures, and at least some reporting of changes in success rates (rather than percent decrease in pain) for groups. There was some potential for bias because treating physicians were unblinded.

Results have been reported to the FDA from multicenter, double-blind, sham-controlled trials delivering ESWT with the Orthospec™, Orthopedic ESWT, and Orbasone™ Pain Relief System. Efficacy of the Orthospec™[11] was examined in 172 participants with chronic proximal plantar fasciitis failing conservative therapy. Patients were randomized to ESWT or sham treatments in a 2 to 1 ratio. At 3 months, the ESWT arm had less investigator-assessed pain with application of a pressure sensor (0.94 points lower on a 10-point VAS, 95% CI: 0.02 to 1.87), but there was no difference in patient-assessed activity improvement and function between ESWT and sham groups. The Orbasone™[12,13] trial included 179 participants with chronic proximal plantar fasciitis randomized to active or sham treatment. At 3 months, both active and sham groups improved in patient-assessed pain on awakening (by 4.6 and 2.3 points, respectively, on a 10-point VAS; crude difference between groups at 3 months of 2.3, 95% CI: 1.5 to 3.3). While this trial reported that ESWT was associated with significantly faster improvement
in a mixed-effects regression model, insufficient details were provided to evaluate the analyses. Although these devices are approved by the FDA for treatment of chronic plantar fasciitis and examined for efficacy in apparently well-designed, double-blind RCTs, definitive, clinically meaningful treatment benefits at three months were not apparent, nor was it evident that the longer-term disease natural history was altered.

The systematic reviews described previously included several RCTs that are detailed below.

Gerdesmeyer et al. reported on a multicenter double-blind RCT of radial ESWT (rESWT) conducted for FDA premarket approval (PMA) of the Dolorclast (EMS Electro Medical Systems) that included 251 patients with heel pain for at least six months and failure of at least two nonpharmacological and two pharmacological treatments.\[^{14}\] Outcomes were composite heel pain (pain on first steps of the day, with activity, and as measured with Dolormeter), change in VAS scores, and Roles and Maudsley score measured at 12 weeks and 12 months. Success was defined as at least 60% improvement in two of three VAS scores OR the patient had to be able to work and complete activities of daily living, had to be satisfied with the outcome of the treatment, and must not have required any other treatment to control heel pain. Secondary outcomes measured at 12 weeks including changes in Roles and Maudsley score, SF-36 physical percent changes, SF-36 mental percent changes, investigator’s judgment of effectiveness, patient’s judgment of therapy satisfaction, and patient recommendation of therapy to a friend. At 12-week follow-up rESWT was followed by a statistically significant decrease of the composite VAS score of heel pain by (72.1% vs 44.7% after sham), but the final VAS scores were not provided. Significant reductions in individual VAS scores with ESRT compared to sham were found for heel pain during daily activities (60% vs 40.68%) and heel pain after application of Dolormeter (52.85% vs. 39.66%), with no difference in heel pain when taking first steps in the morning. The success rate for the composite score was 61% vs. 42% (P=0.002). Statistically significant differences favoring ESWT were noted on all secondary measures at 12 months. The limitations of this study prevent definite conclusions from being reached. These include the limited data concerning specific outcomes (e.g., presenting percent changes rather than actual results of measures); inadequate description of prior treatment (or intensity of treatment) provided before referral to the study; use of the composite outcome measure; and no data on the use of rescue medication. In addition, the clinical significance of changes (and relative changes) in outcome measures is uncertain, and there are questions about the adequacy of patient blinding.

Kudo et al. reported a statistically significant difference in improvement in mean pain score on first walking in the morning between the active treatment and placebo, three months after treatment.\[^{15}\] There were no significant differences in other measures. It should be noted that the placebo group also reported significant improvement in pain from baseline. Intention-to-treat analysis was not reported in this study, and there was a significant difference between groups in blinding verification, with more active treatment patients reporting that they believed they received the active treatment, thus potentially biasing results.

Malay and colleagues randomized 172 patients at a 2:1 ratio to either active ESWT (n=115) or sham (n=57).\[^{16}\] Subjects and assessors were blinded, while non-blinded investigators administered the single treatment session. Follow-up was three months. Both groups reported improvement from baseline, with significantly more responders (decrease from baseline of 50% or more with a visual analog scale (VAS) score =4) in the active ESWT group than in the sham group (42.9% and 19.6%, respectively; p=.003). Between-group differences in reduction in heel pain reached statistical significance for both blind assessor’s objective and participants’ subjective assessment (p=.045 and p<.001, respectively). The reduction in pain was statistically significantly greater in the treatment
group than in the sham group in the absence of heel spur (p=.012) but not when heel spur was present (p=.96). The reduction in the use of pain medication was also significantly greater in the treatment group (p<.001). It is interesting to note that despite the report of greater reduction in pain in the treatment group there was no significant between-group difference in self-assessment of activity and functional levels. This study adds to the number of randomized controlled clinical trials reporting significantly greater symptom improvement with active treatment compared with sham. However, conclusions related to health outcomes cannot be reached due to the short-term follow-up period, the 2:1 patient ratio and the administration of treatment by non-blinded investigators. In addition, it is difficult to compare these results with other studies due to differences in treatment protocol and patient selection methods.

Additional randomized controlled trials have reported similar or improved pain reduction with ESWT in patients with plantar fasciitis compared to placebo.[10,17-24] In addition, improvement in short-term functional status was also reported.[23,24] However, there are many limitations in interpreting these findings. Individual RCTs included in the reviews and meta-analyses reported inconsistent results and heterogeneity in the studies sometimes precluded meta-analysis of pooled data. Outcomes measured and study protocols, e.g., dose intensities, type of shockwaves and frequency of treatments, also often lacked uniformity. Additionally, because plantar fasciitis often resolves within a 6-month period, longer follow-up studies are needed to compare ESWT results with the natural resolution of the condition. The clinical significance of results reported at shorter follow-up, such as 3 months, is uncertain. As such, these trials and a pooling of their outcomes do not make a significant impact on the interpretation of the findings reached in the larger, higher-quality trials described above.

Several recent smaller randomized studies have compared ESWT with other treatments, including corticosteroid injections. One of these, by Eslamian et al., randomized 20 patients with chronic plantar fasciitis each to ESWT and corticosteroid injections. The authors reported that both interventions led to improvements in pain and functional ability after two months, but the treatment outcomes were not significantly different between groups.[25] Another study by Mardani-Kavi et al. comparing these two treatments in 68 patients reported greater pain reduction in the corticosteroid injection group than in the ESWT group.[26] Additionally, ESWT was compared with botulinum toxin type A injection in a trial with 72 patients described by Roca et al., which found that ESWT was superior for pain relief.[27]

Nonrandomized Studies

Nonrandomized studies[28,29] have also reported outcomes after ESWT for plantar fasciitis, but given the lack of randomized trial design, these studies do not provide additional evidence regarding ESWT’s efficacy compared with alternative therapies.

Conclusion

There are numerous RCTs identified, including several well-designed double-blinded RCTs, which have evaluated ESWT for treatment of plantar fasciitis. The evidence is mixed, with some studies reporting a benefit and others reporting no benefit. The reasons for this variability in the literature are not clear. Definitive, clinically meaningful treatment benefits at 3 months are not apparent, nor is it evident that the long term natural course of disease is altered with ESWT. Therefore, no reliable conclusions can be reached concerning ESWT for the treatment of plantar fasciitis.

Tendinitis of the Shoulder
A systematic review and network meta-analysis published in 2016 by Arirachakaran et al. compared clinical outcomes between ESWT, ultrasound-guided percutaneous lavage (barbotage), subacromial corticosteroid injection, and combined treatment for rotator cuff calcific tendinopathy. The clinical outcomes in this study were pain (VAS), shoulder function (Constant Murley score) and size of calcium deposit. The authors identified 7 relevant studies, including 6 with ESWT: 4 that compared ESWT to placebo, and one each comparing ESWT to corticosteroid injection plus barbotage and ESWT plus barbotage. The results of the network meta-analysis, which allows indirect comparisons between active treatments, indicated that while ESWT significantly improved pain and function compared with placebo, barbotage plus corticosteroid injections significantly improved pain (VAS) and calcium deposit size compared to the other treatments. The authors noted that the majority of the studies were unclear regarding randomization sequence generation and allocation concealment, which could lead to selection bias or confounding.

A 2015 systematic review by Yu et al. assessed the effectiveness of various passive physical modalities for shoulder pain and included 11 studies considered to be at low risk of bias, with 5 studies that reported on ESWT. Three, published from 2003 to 2011, were for calcific shoulder tendinopathy, including 1 RCT comparing high-energy ESWT with low-energy ESWT (N=80), 1 RCT comparing rESWT with sham ESWT (N=90), and 1 RCT comparing high-energy ESWT with low-energy ESWT and sham ESWT (N=144). All 3 trials reported statistically significant differences between groups, favoring ESWT, for change in shoulder pain VAS score.

In 2014, Verstraelen and colleagues conducted a systematic review of RCTs evaluating the efficacy of high versus low energy ESWT as a treatment for calcifying tendinitis of the shoulder in 5 RCTs (n=359). Eligible for inclusion were all RCTs that compared high-energy ESWT (> 0.28 mJ/mm²) with low-energy ESWT (< 0.08 mJ/mm²). All 5 trials indicated greater improvement in functional outcome in patients treated with high-energy ESWT when compared to low-energy ESWT at 3 and 6 month follow-up. The 3 month mean difference in outcomes, measured by the Constant-Murley score, was 9.88 (95% CI, 9.04-10.72, p<0.001); however, the 6 month data could not be pooled.

In 2014, Bannuru and colleagues published a systematic review of RCTs comparing high-energy ESWT with placebo or low-energy ESWT for the treatment of patients with calcific and noncalcific shoulder tendinitis. Twenty-eight studies were included in the review. In 7 studies comparing ESWT with placebo for calcific tendinitis, all studies reported significant improvements in pain or functional outcomes associated with ESWT. Only high-energy ESWT was consistently associated with significant improvements in both pain and functional outcomes. In 8 studies comparing high- with low- energy ESWT for calcific tendinitis, studies did not demonstrate significant improvements in pain outcomes, although shoulder function was improved with high-energy ESWT. Authors indicated that all included RCTs were limited by small sample size and heterogeneous design, and in general, trials were low quality and associated with a high risk of bias.

In a 2013 systematic review and meta-analyses, Ioppolo et al. included 6 RCTs on ESWT compared with sham treatment or placebo for calcific shoulder tendinopathy. Greater shoulder function and pain improvements were found at 6 months with ESWT over placebo. Most studies were considered to be low quality.

In 2011, Huisstede et al. published a systematic review that included 17 RCTs of calcific (RCTs=11) and non-calcific (RCTs=6) tendinopathy of the rotator cuff. Moderate quality evidence was found for
the efficacy of ESWT versus placebo for calcific tendinopathy, but not for noncalcific tendinopathy. High-frequency ESWT was found to be more efficacious than low-frequency ESWT for calcific tendinopathy. Authors reported the most prevalent methodological limitations were a lack of care-giver blinding (65%) and a lack of intention-to-treat analysis (35%). Due to the heterogeneity of the included studies, results could not be pooled for analysis.

Randomized Controlled Trials (RCTs)

RCTs not represented in the systematic reviews described above include a study published in 2009, Schofer et al. compared the effects of high-energy versus low-energy ESWT in 40 patients with rotator cuff tendinopathy.\[36\] An increase in function and reduction of pain were found in both groups (p<0.001). Although improvement in Constant score was greater in the high-energy group, there were no statistically significant differences in any outcomes studied (Constant score, pain, subjective improvement) at 12 weeks and 1 year after treatment.

Several other trials have been published; however, these studies have similar methodological limitations, such as small study population, short duration of follow-up, and/or lack of double-blinding.\[37-41\]

Conclusion

In summary, a number of RCTs have evaluated the use of ESWT to treat shoulder tendinopathy, which have been summarized in several systematic reviews and meta-analyses. Although some trials have reported a benefit in terms of pain and functional outcomes, particularly for high-energy ESWT for calcific tendinopathy, many available trials are considered poor quality. As a result, there is insufficient evidence to permit conclusions concerning whether ESWT improves outcomes for patients with tendinitis of the shoulder.

Tendinitis of the Elbow (Lateral Epicondylitis)

Systematic Reviews

Six randomized, double-blinded, placebo-controlled trials enrolling 808 patients with lateral epicondylitis met the inclusion criteria for the 2004 TEC Assessment.\[42\] Two studies were rated as fair in quality due to 1) small sample size and group differences at baseline in duration of symptoms and prior treatment, yielding a possibility of selection bias\[43\]; and 2) lack of accounting for dropouts and intent-to-treat analysis.\[44\] Four trials were rated “good” quality. These include the SONOCUR trial, with 114 patients, which found that at 3 months the main outcome measures (Upper Extremity Function Scale and self-reported pain scale) showed greater improvement in the ESWT group, compared with the placebo group.\[45\] The OssaTron trial randomized 183 patients to a single session of high-energy or sham ESWT and after 8-weeks of follow-up, the ESWT group had a greater rate of treatment success than the placebo group, but self-reported pain and pain medication use was not significantly different.\[46\] The third trial randomized 272 patients to 3 sessions of low-energy or sham ESWT, and found no significant differences between groups for treatment success rate, pain assessment measures, or grip strength.\[13\] The final trial included 78 tennis players and found that the group to 3 treatments at weekly intervals of low-energy ESWT had significantly improved pain and function scores, but not grip strength at 3 months follow-up.\[47\] Overall, the TEC Assessment concluded that the available data did not provide strong and consistent evidence that ESWT improved outcomes of chronic lateral epicondylitis.
Other systematic reviews published since the 2004 TEC Assessment have come to similar conclusions. A 2005 Cochrane review concluded “there is ‘Platinum’ level evidence [the strongest level of evidence] that shock wave therapy provides little or no benefit in terms of pain and function in lateral elbow pain.”[48] A 2013 systematic review of electrophysical therapies for epicondylitis concluded that the evidence conflicting on the short-term benefits of ESWT.[49] No evidence was found demonstrating any long term benefits with ESWT over placebo for epicondylitis treatment.

Randomized Controlled Trials (RCTs)

Several RCTs have been published on the use of ESWT to treat lateral tendinitis since the most recent systematic review. A double-blind RCT published in 2016 by Capan et al. compared three weekly rESWT sessions (2000 pulses of 10Hz at a 1.8 bar of air pressure) with sham treatment in 56 patients that had not responded to previous treatments.[50] The outcomes assessed were pain and function (VAS, Roles and Maudsley score, and Patient-Rated Tennis Elbow Evaluation), and grip strength (hand dynamometer). Both groups showed significant improvement at one and three months posttreatment, and there was no significant difference between them.

In a study published in 2015, Beyazal and Devrimsel compared ESWT with corticosteroid injection.[51] This trial randomized 64 patients, and evaluated hand grip strength and pain (VAS and short-form McGill pain questionnaire) at 4 and 12 weeks posttreatment. After 4 weeks of followup, the ESWT group showed improvement in the VAS score, but other assessments did not differ between groups. At 12 weeks posttreatment, there was a statistically significant difference in the percentages of improvements between the groups favoring ESWT for all three parameters. This study was limited by a lack of blinding, which increases the risk of bias, and reported only percentages of score improvement.

Also published in 2015, Lizis compared ESWT with therapeutic ultrasound among 50 patients with chronic tennis elbow.[52] For most pain measures assessed, pain was lower in the ESWT group immediately posttreatment and at 3 months, with the exception of pain on gripping, which was higher in the ESWT group. While trial results favored ESWT, there was a high risk of bias due to a number of factors, particularly lack of blinding of participants and outcome assessors, which make interpretation of results difficult.

Additional randomized controlled trials of ESWT for elbow tendinopathy have been published. However, these trials have significant methodological limitations (e.g., small study populations, short duration of follow-up) and as such do not warrant detailed discussion.[53,54]

Nonrandomized Studies

Nonrandomized observational studies have reported functional outcomes after ESWT for epicondylitis; however, these studies provided limited evidence about the comparative effectiveness of ESWT for lateral epicondylitis compared with other therapies.

Conclusion

In summary, the most direct evidence regarding the use of ESWT to treat lateral epicondylitis is derived from many small RCTs, which have not consistently demonstrated outcome improvements beyond those observed in control groups with ESWT. Therefore it is not possible to reach conclusions concerning the overall effect of ESWT on health outcomes for chronic lateral epicondylitis. It is not known whether differing results are due to methodological bias or to differences in the study populations and
interventions. Further, a Cochrane review, which included nine placebo-controlled trials with 1,006 participants, concluded “there is ‘Platinum’ level evidence [the strongest level of evidence] that shock wave therapy provides little or no benefit in terms of pain and function in lateral elbow pain.”[48,56] The authors noted that when available data from the randomized trials was pooled, most benefits observed in the positive trials were no longer statistically significant.

Achilles Tendinopathy

Systematic Reviews

Al-Abbad and Simon published a systematic review of 6 studies on ESWT for Achilles tendinopathy.[57] Included in the review were 4 small RCTs and 2 cohort studies. Satisfactory evidence was found demonstrating ESWT effectiveness in the treatment of Achilles tendinopathy at 3 months in 4 studies; however, 2 of the RCTs reviewed found no significant difference between ESWT and placebo in the treatment of Achilles tendinopathy.[58,59]

In 2015, Mani-Babu et al. reported results of a systematic review and meta-analysis of studies evaluating ESWT for lower limb tendinopathies, including Achilles tendinopathy, patellar tendinopathy, and greater trochanteric pain syndrome.[60] The review included 20 studies overall, 11 of which evaluated ESWT for Achilles tendinopathy, including 5 RCTs, 4 cohort studies, and 2 case-control studies. In pooled analysis, the authors reported that ESWT was associated with greater short term (<12 months) and long-term (>12 months) improvements in pain and function compared with nonoperative treatments, including rest, footwear modifications, anti-inflammatory medication, and gastrocnemius-soleus stretching and strengthening. The authors noted that findings from RCTs of ESWT for Achilles tendinopathy are contradictory, but that there is at least some evidence for short-term improvements in function with ESWT.

Randomized Controlled Trials

Costa et al. conducted a randomized, double-blind, placebo-controlled trial of ESWT for chronic Achilles tendon pain treated monthly for three months.[58] The study randomized 49 participants and was powered to detect a 50% reduction in VAS pain scores. No difference in pain relief at rest or during sport participation was found at 1 year. Two older ESWT-treated participants experienced tendon ruptures.

Rasmussen et al. reported a single-center double-blind controlled trial with 48 patients, half of them randomized after four weeks of conservative treatment to four sessions of active rESWT and half to sham ESWT.[59] Primary endpoints were American Orthopaedic Foot and Ankle Society (AOFAS) score measuring function, pain, and alignment and pain on visual analog scale. AOFAS score after treatment increased from 70 (SD 6.8) to 88 (SD 10) in the ESWT group and from 74 (SD 12) to 81 (SD 16) in the control (p=0.05). Pain was reduced in both groups with no statistically significant difference between groups. The authors noted that the AOFAS score may not be appropriate for the evaluation of treatment of Achilles tendinopathy.

Conclusion

In summary, there is insufficient evidence to permit conclusions regarding the use of ESWT upon improved health outcomes for patients with tendinitis of the Achilles.
**Patellar Tendinopathy**

**Systematic Reviews**

Van Leeuwen et al\[61\] conducted a literature review to study the effectiveness of ESWT for patellar tendinopathy and to draft a treatment protocol which included resulted in a review of 7 articles. The authors found that most studies had methodological deficiencies, small numbers and/or short follow-up periods, and treatment parameters varied among studies. They concluded that ESWT appears to be safe and promising treatment but that a treatment protocol cannot be recommended and further basic and clinical research is required. In an RCT of patients with chronic patellar tendinopathy (N=46), despite at least 12 weeks of nonsurgical management, improvements in pain and functional outcomes were significantly greater (p<0.05) with plasma-rich protein injections than ESWT at 6 and 12 months, respectively.

In the 2015 systematic review and meta-analysis of ESWT for lower extremity tendinopathies by Mani-Babu et al, described above, the authors identified 7 studies of ESWT for patellar tendinopathy, including 2 RCTs, 1 quasi-RCT, 1 retrospective cross-sectional study, 2 prospective cohort studies, and 1 case-control study.\[60\] Two RCTs came to different conclusions: one RCT found no difference in outcomes between ESWT and placebo at 1, 12, or 22 weeks, whereas an earlier RCT found improved outcomes on vertical jump test and Victorian Institute of Sport Assessment Questionnaire–Patellar (VISA-P) scores at 12 weeks with ESWT compared with placebo. Two studies which evaluated outcomes beyond 24 months found that ESWT was comparable with patellar tenotomy surgery and better than nonoperative treatments.

**Medial Tibial Stress Syndrome (MTSS) (“shin splints”)**

**Systematic Reviews**

A single systematic review was identified that addressed the use of ESWT for medial tibial stress syndrome (MTSS). This review, published in 2013 by Winters et al., evaluated the evidence for a number of treatments for MTSS, including iontophoresis, phonophoresis, ice massage, ultrasound, low-energy laser treatment, periosteal pecking (needling), stretching and strengthening exercises, sports compression stockings, lower leg braces, extracorporeal shockwave therapy, and pulsed electromagnetic field therapy.\[62\] There were 11 trials included in the analysis: 9 RCTs and 2 nonrandomized trials. The authors indicated that all of the RCTs had a high risk of bias and that the nonrandomized trials were of poor quality, and for this reason, no specific treatment could be recommended.

**Randomized Controlled Trials (RCTs)**

No randomized controlled trials of ESWT for MTSS were identified.

**Nonrandomized Studies**

A prospective, controlled study on the use of ESWT for MTSS in 42 athletes was published in 2012 by Moen et al.\[63\] One group of patients was treated with a graded running program alone, while the other group was treated with the running program and 5 ESWT sessions in 9 weeks. The ESWT group was reported to have a significantly reduced time to recovery, defined as the ability to run 18 minutes consecutively without pain at a fixed intensity, which was reported as the main outcome measured. This
study is significantly limited by the lack of blinding or randomization and the lack of validated outcome measures.

In 2010, Rompe et al. published a report on the use of ESWT in (MTSS).[64] In this non-randomized cohort study, 47 patients with MTSS for at least 6 months received 3 weekly sessions of rESWT, and were compared to 47 age-matched controls at four months. Mild adverse events were noted in ten patients: skin reddening in 2 patients and pain during the procedure in 8 patients. Patients rated their condition on a six-point Likert scale. Successful treatment was defined as self-rating “completely recovered” or “much improved”. The authors report a significant success rate of 64% (30/47) in the treatment group compared to 30% (14/47) in the control group. This study represents another potential use for ESWT. In a letter to the editor, Barnes has raised several limitations of this study. In a nonrandomized study, the possibility of selection bias is introduced. This is particularly problematic when outcomes are patient-reported. Larger, randomized trials are needed.

**Spasticity**

**Systematic Reviews**

Lee et al.[65] conducted a systematic review and meta-analysis of studies evaluating ESWT for patients with spasticity secondary to a brain injury. Studies were included that evaluated ESWT as sole therapy and that reported pre- and post-intervention modified Ashworth Scale scores. Five studies were included examining spasticity in the ankle plantar flexor and 1 examining spasticity in the wrist and finger flexors; 3 studies evaluated post-stroke spasticity and 2 evaluated spasticity associated with cerebral palsy. Immediately post-ESWT, modified Ashworth Scale scores improved significantly compared with baseline (standardized mean difference [SMD] -0.792; 95% CI -1.001 to -0.583; \(P<0.001\)). After 4 weeks post- ESWT, modified Ashworth Scale scores continued to demonstrate significant improvements compared with baseline (SMD -0.735; 95% CI -0.951 to -0.519; \(P<0.001\)). A strength of this meta-analysis is that it used a consistent and well-definable outcome measure. However, the modified Ashworth Scale does not account for certain clinically-important factors related to spasticity, including pain and functional impairment.

**Randomized Controlled Trials (RCTs)**

Two single-blind RCTs were published in 2016, assessing the effects of rESWT on upper limp spasticity in patients with chronic stroke. One of these, reported by Li et al., randomized 60 patients into three equal groups with the following treatments: 1) one session of rESWT per week for three weeks, 2) one single session of rESWT, and 3) one session of sham rESWT per week for three weeks.[66] The primary outcome of the study was the Modified Ashworth Scale (MAS) score for the hand and wrist, and the secondary outcome was the Fugl-Meyer Assessment score. The authors reported that groups receiving rESTW had significant reductions in spasticity, with the reductions lasting for 8-12 weeks for the single session group and at least 16 weeks for the three session group.

The second study, by Dymarek et al., randomized 60 patients to two either rESWT or placebo.[67] The outcomes assessed in this study were the MAS score for three joint (fingers, elbow, and radiocarpal), surface electromyography (sEMG) of two forearm muscles, and infrared thermal imaging. Patients in the rESWT group had a reduced MAS score for the finger joints, a decrease in sEMG activity in the two muscles, and increases in IRT detection.
A small, 2011 RCT examined the efficacy and safety of rESWT in the treatment of spasticity in patients with cerebral palsy.[68] The 15 patients in this study were divided into 3 groups (ESWT in a spastic muscle, ESWT in both spastic and antagonistic muscle, and placebo ESWT) and treated in 3 weekly sessions. Spasticity was evaluated in the lower limbs by passive range of motion with a goniometer and in the upper limbs with the Ashworth scale (0-4, no spasticity to severe spasticity) at 1, 2, and 3 months after treatment. Blinded evaluation showed significant differences between the ESWT and placebo groups for range of motion and Ashworth scale. For the group in which only the spastic muscle was treated, there was an improvement of 1 point on the Ashworth scale (p=0.05 in comparison with placebo); for the group in both which the spastic and antagonistic muscle was treated, there was an improvement of 0.5 points (not statistically significant in comparison with placebo); and for the placebo group there was no change. The significant improvements were maintained at 2 months after treatment, but not at 3 months.

Additional RCTs with large sample sizes are needed to permit conclusions regarding the efficacy of this technology on spasticity.

Nonrandomized Study

Several nonrandomized studies have evaluated the efficacy of ESWT for spasticity treatment. A prospective case-control study by Wang et al. assessed rESWT for spastic plantar flexor muscles in 66 children, aged 1 to 5 years, with cerebral palsy.[69] Treatment consisted of 1 ESWT session per week for 3 months, in combination with traditional conservative therapy. The control group had conservative therapy alone. Conservative therapy in this study included physical therapy, Chinese massage, meridian mediation, and muscle stimulation. The parents of the patients elected which treatment the patients received, with 34 children in the rESWT group and 32 in the traditional conservative therapy. Improvements in the Modified Ashworth Scale grade, passive range of motion, and Gross Motor Function Measure-88 were reported for the rESWT group, relative to the control group. However, the lack of randomization and blinding in this study are serious limitations.

Daliri et al evaluated the efficacy of a single session of ESWT for treatment of post-stroke wrist flexor spasticity in a single-blinded trial in which each patient received both sham control and active stimulation.[70] Fifteen patients with post-stroke spasticity at a mean 30 months post-stroke were included, each of whom received 1 sham stimulation followed 1 week later by 1 active ESWT treatment. Investigators were not blinded. Outcomes evaluated included the modified Ashworth Scale to evaluate spasticity intensity, the Brunnstrom recovery stage tool to assess motor recovery, and the neurophysiological measure of H_max/M_max to measure alpha motor neuron excitability. Ashworth scores and Brunnstrom recovery stage scores did not improve after sham treatment. Ashworth Scale scores improved significantly from baseline (mean 3) to after active ESWT treatment (mean score 2, 2, and 2 immediately post-therapy, 1 week post-therapy, and 5 weeks post-therapy, respectively; P<0.05). H_max/M_max ratio improved from 2.30 before therapy to 1 week after active ESWT (P=0.047). Brunnstrom recovery stage scores did not significantly improve after active ESWT. Given the lack of a comparison with a control group, this study provides limited evidence about the efficacy of ESWT for post-stroke spasticity.

In 2014, Santamato and colleagues evaluated ESWT for the treatment of post-stroke lower limb spasticity in 23 patients. Authors concluded that ESWT was a safe and effective treatment for of poststroke plantar-flexor muscles spasticity, reducing muscle tone and improving passive ankle dorsiflexion motion; however, this study was limited by a lack of randomization, small sample size and short-term follow-up.[71]
Summary

In summary, a relatively small body of evidence, with limited RCT evidence, is available to evaluate the use of ESWT for spasticity. Several studies have demonstrated improvements in spasticity measures after ESWT. Further controlled trials are needed to determine whether ESWT leads to clinically meaningful improvements in pain and/or functional outcomes for spasticity.

Avascular Necrosis (Osteonecrosis) of the Femoral Head

Systematic Review

A systematic review of ESWT in osteonecrosis (avascular necrosis) of the femoral head was conducted by Alves et al in 2009.[72] Only 5 articles, all from non-U.S. sites, were identified: 2 RCTs, 1 comparative study, 1 open-label study, and 1 case report for a total of 133 patients. Several studies were from one center in Taiwan. Of the 2 RCTs, one (n=48) was randomized to the use of concomitant alendronate; ESWT treatments were in both arms of the study and ESWT was therefore not the comparator. The other RCT compared ESWT with a standard surgical procedure. All results noted a reduction in pain over the time of the study, which was attributed by each of the study’s authors to a positive effect of ESWT. However, the authors of this review noted the limitations of the available evidence: lack of double-blind design, small numbers of patients included, short duration of follow-up, and nonstandard intervention (e.g. energy level and number of treatments).

Nonrandomized Studies

A comparative study not included in the systematic review by Alves et al. was published Chen and colleagues. These study authors reported on the experiences of 17 patients with bilateral hip osteonecrosis who were treated with total hip arthroplasty on one and ESWT on the other side.[73] Each patient was evaluated at baseline and after treatment utilizing the visual analog scale (VAS) for pain and Harris hip score, a composite measure of pain and hip function. There was a significant reduction in scores before and after treatment in both treatment groups. Hips treated with ESWT were also evaluated for radiographic reduction of bone marrow edema on magnetic resonance imaging (MRI), which also appeared to be reduced. The authors then compared the ESWT-treated data to the total hip arthroplasty results, stating that the magnitude of improvement was greater for the ESWT-treated hips. However, hips were not randomized to treatment intervention; the side with the greater degree of disease was treated with surgery in each case. Moreover, time between hip interventions within the same patient averaged 17.3 months, with a range of 6 to 36 months; in all but one case, surgery preceded ESWT. Therefore, conclusions about the superiority of one intervention over the other cannot be made.

Summary

A limited body of evidence addresses ESWT for osteonecrosis of the femoral head. Hence, the available evidence is insufficient to allow conclusions about the efficacy of ESWT for osteonecrosis.

Nonunion, Delayed Union and Acute Fractures

Randomized Controlled Trials (RCTs)
Cacchio and colleagues compared surgery to low- and high-energy ESWT in 126 patients.\textsuperscript{[74]} Patients were identified for participation in the study if referred to one of three Italian centers with nonunion fractures, here defined as at least six months without evidence of radiographic healing. The primary endpoint was radiographic evidence of healing. Secondary endpoint data of pain and functional status were collected by blinded evaluators. Neither patients nor treating physicians were blinded. At six months, rates in the lower energy ESWT, higher energy ESWT and surgical arms had similar healing rates (70%, 71% and 73%, respectively). There was no significant difference among the groups at this stage. All groups healing rates improved at further follow-up at 12 and 24 months without significant between-group differences. Secondary endpoints of pain and disability were also examined, and were similar. The authors believe this to be the first RCT of its kind, and encourage additional study. Lack of blinding may have led to differing levels of participation in other aspects of the treatment protocol.

Wang and colleagues randomized 56 trauma patients with femur or tibia fractures to a surgical fixation with or without subsequent single ESWT treatment.\textsuperscript{[75]} Patients were evaluated for pain and percent weight-bearing capability on the affected leg by an independent, blinded evaluator. Radiographs taken at these same intervals were evaluated by a radiologist blinded to study group for fracture healing or nonunion. Both groups showed significant improvement in pain scores and weight-bearing status. Between-group comparisons of pain by VAS, and weight bearing favored study patients at each interval. At six months, patients who had received ESWT had VAS scores of 1.19 compared to 2.47 in the control group (p<0.001); mean percentage of weight bearing at 6 months was 87% versus 78%, respectively (p=0.01). Radiographic evidence of union at each interval also favored the study group. At 6 months, 63% (17/27) of the study group achieved fracture union compared to 20% (6/30) in the control group (p<0.001). The authors note some limitations to the study: the small number of patients in the study, surgeries performed by multiple surgeons and questions regarding adequacy of randomization.

In summary, the methodological limitations in the evidence do not permit reliable conclusions regarding the effectiveness of ESWT for fracture nonunion, delayed union, and acute fractures.

Other Musculoskeletal and Neurologic Conditions

Other possible uses of ESWL noted in the literature but not supported by evidence from randomized controlled clinical trials include: osteochondritis dissecans, patellar tendinitis and other forms of chronic tendinitis, and dystonia.\textsuperscript{[60,76]}

Specifically, ESWT has been investigated for treatment of coccydynia in a small case series of 2 patients\textsuperscript{[77]} and painful neuromas at amputation sites in a small RCT of 30 patients.\textsuperscript{[78]}

In the 2014 systematic review and meta-analysis of ESWT for lower extremity tendinopathies by Mani Babu et al.\textsuperscript{[60]}, described in previous sections, the study authors reviewed 2 studies of ESWT for greater trochanteric pain syndrome, including 1 quasi-RCT comparing ESWT with home therapy or corticosteroid injection and 1 case-control study comparing ESWT with placebo. ESWT was associated with some benefits compared with placebo or hone therapy.

Clinical Practice Guidelines

The 2010 American College of Foot and Ankle Surgeons (ACFAS) practice guideline on the treatment of heel pain identifies ESWT as a third tier treatment modality in patients who have failed other interventions, including steroid injection.\textsuperscript{[79]} The guideline recommends ESWT as a reasonable alternative to surgery. However, the guideline references the same unreliable studies considered above.
Summary

There is not enough research to show that extracorporeal shock wave treatment (ESWT) as a treatment for any musculoskeletal conditions improves health outcomes. Differences in treatment methods among studies make generalizing the results of multiple studies difficult, and the action of ESWT is not completely understandable. More research is needed with large numbers of patients and long-term follow-up. Therefore, ESWT is considered investigational for all musculoskeletal indications.

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**CROSS REFERENCES**

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