

General

Extracorporeal Shockwave Therapy in Pain Management – an In-Depth Narrative Review

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Purpose of Review

The purpose of this narrative review is to explain the cellular mechanisms behind chronic pain, the mechanisms behind extracorporeal shockwave therapy, and its efficacy for the treatment of various chronic pain conditions including tendinopathies, greater trochanteric pain, de quervain tenosynovitis, myofascial pain, plantar fasciitis, fibromyalgia, osteoarthritis, fractures, osteonecrosis, bone edema, coccydynia, low back pain, chronic pelvic pain syndrome/chronic prostatitis, ulcers, and carpal tunnel syndrome.

Recent Findings

Many recent clinical trials and meta-analyses from the year 2024 overall supported the efficacy of extracorporeal shockwave therapy for the treatment of chronic pain conditions with minimal adverse effects.

Summary

Extracorporeal shockwave therapy is a novel technique that uses mechanotransduction to induce a cellular response that prevents central sensitization, reduces inflammation, and contributes to healing that alleviates pain. The specific mechanisms through which extracorporeal shockwave therapy are largely unknown or poorly understood. A literature search of Scopus, PubMed, Embase, and the Cochrane Database of Systematic Reviews was conducted to identify 84 studies from 2000-2024 evaluating the efficacy of extracorporeal shockwave therapy for the treatment of chronic pain conditions. The results indicate that extracorporeal shockwave therapy holds strong promise for the treatment of numerous chronic pain pathologies with minimal adverse effects and should be studied further.

INTRODUCTION

According to the International Association for the Study of Pain (IASP), pain is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage.^{1,2} Chronic pain on the other hand, refers to

a type of pain that lasts longer than 3 months, with the lower extremities, back, and head being the most common pain locations.³ In recent literature, chronic pain has been identified as one of the most prevalent causes of disability worldwide, affecting approximately 20% of the global population.^{3,4} This represents a significant burden for people

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within the countries affected, as the condition is known to have a social and economic impact on health care systems and employment activity, often due to indirect costs such as work absenteeism and disability compensation.⁴ One report by the Institute of Medicine suggested that chronic pain costs the U.S. somewhere between \$560 and \$635 billion per year in medical costs and lost productivity.⁵ With regard to the demographics most impacted, data from the CDC found higher prevalence rates of chronic pain in women, military veterans, people from lower socioeconomic backgrounds, and people living in rural areas.^{2,6} Studies investigating racial and ethnical prevalence are inconclusive, with some reporting the highest incidence to be among non-Hispanic White people, and others reporting a higher prevalence in African American and indigenous populations.² Chronic pain incidence was also found to increase with age, with one study finding a higher percentage in those aged 45-64 (10.3%) and over 65 (11.8%) when compared with those aged 18-29 (2.2%).⁶ Alleviating chronic pain, whether it be by treating the symptoms (neuropathic pain, nociceptive pain, etc.) or the condition itself, should be an important goal for the pain care community, as untreated pain is known to negatively affect brain function, sleep, mental health, sexual function, cardiovascular health, and overall quality of life.^{7,8}

Current treatments for chronic pain are often multimodal in their approach, and can include non-invasive methods such as exercise, pain education, behavioral strategies, self-monitoring, and goal setting strategies, or more invasive methods that are usually reserved for more advanced pathologies such as laminectomy, hip replacement, knee arthroplasty, and spinal fusion.^{4,7} Exercise therapy is the most common non-invasive self-management strategy, involving and is correlated with benefits such as improved sleep quality, endorphin secretion, and reversed deconditioning.² It is hard Cognitive behavioral therapy (CBT), another non-invasive therapy, refers to the restricting of attitudes, maladaptive beliefs, and behaviors that contribute to the overall burden of living with chronic pain.² Results from studies evaluating CBT seem to indicate efficacy, as a systematic review found CBT to provide slight benefit in the short term when compared with usual treatment, but not when compared to an active control.⁹ Lastly, non-opioid pharmacological management is another form of non-invasive pain therapy that varies based on the type of pain that is being treated.² Analgesic antidepressants and antiepileptic drugs are the first-line medications given for neuropathic pain – a paradigm based on numerous placebo-controlled clinical trials of moderate and high quality.² Conversely, oral non-steroidal anti-inflammatory (NSAIDs) and topical drugs are generally the first-line medications given for non-neuropathic pain caused by conditions such as osteoarthritis, back pain, tendonitis, and other inflammatory chronic conditions.¹⁰ Focusing on pharmacological treatment devoid the use of opioids is a notable improvement in pain management because chronic pain treated with opioids has been found to correlate with opioid use disorder, which can worsen symptoms, harm quality of life, and complicate treatment.¹¹⁻¹⁴ When it

comes to invasive treatments, many novel minimally invasive procedures have emerged in the literature and have been preferred to more drastically invasive techniques.¹⁵ For example, procedures like epidural steroid injections may be used for neuropathic pain, while procedures like radiofrequency ablation, spinal cord stimulation, coeliac plexus neurolysis, injection of biologics, and hyperbaric oxygen therapy may be used for nociceptive pain, visceral pain, and other mixed conditions.^{2,15-18} Among these novel techniques is Extracorporeal Shockwave Therapy (ESWT), which was recently discovered for use in chronic pain conditions and has yielded positive outcomes in many clinical trials. Because ESWT has shown such promising results and potential for the future of minimally invasive pain management, it is the primary focus of this review. All of the above techniques are encompassed within the widely accepted best practices for pain management, published in a document in 2019 by the US Department of Health and Human Services, which encourages multidisciplinary approach, a focus on improvement in quality of life, a patient-centered approach, and consideration of the needs of populations that possess unique challenges, such as military personnel, children, people above the age of 65, and racial and ethnic minorities.^{2,19}

METHODS OF LITERATURE SEARCH

A literature search was conducted in July of 2024 for studies published since the year 2000 within the following databases: Scopus, PubMed, Embase, and the Cochrane Database of Systematic Reviews (CDSR). Keywords and search paradigms included “extracorporeal shockwave therapy”, the word “pain” in the article title, abstract, and key words, the word “ESWT” in the article title, abstract, and key words, the word “RSWT” in the article title, abstract, and keywords, and the word “FSWT” in the article title, abstract and keywords. The search was designed to exclude the word “lithotripsy” in the article title, the “sialolithiasis” in the title, the word “lithiasis” in the title, the word “acupuncture” in the title, studies that were not in the final stage of publication, letters, and non-English studies. After the initial search was complete, 2163 articles were identified. After duplicates were removed, 1688 studies remained, including 357 from PubMed, 1093 from Scopus, 231 from Embase, and 7 from CDSR.

This narrative review wanted to focus on the highest forms of evidence for ESWT, and thus we restricted our search to include randomized controlled trials, clinical trial follow-ups, systematic reviews, and meta-analyses. Therefore, after duplicates were removed, titles of articles were screened and excluded for the following reasons: lingering duplicates, lack of relevance, case reports, combined ESWT studies with interventions that didn’t isolate the effect of ESWT, non-systematic reviews, pilot studies, feasibility studies, animal studies, protocol studies, mechanism-based studies, and case series. After title screening, 191 relevant studies were grouped by condition being treated. These relevant studies were then subjected to abstract and full text review and were excluded if they were determined to have

a lack of relevance, and or failed to report pain outcomes specifically. Finally, 84 studies were selected for inclusion in this review, reported in [Tables 1-5](#).

CELLULAR MECHANISMS THAT MODULATE AND CAUSE CHRONIC INFLAMMATORY PAIN

INFLAMMATION

Numerous studies have suggested that inflammation plays a significant role in the induction and maintenance of chronic pain in both neuropathic and non-neuropathic conditions.²⁰⁻²² Inflammation is caused by endogenous mediators released from damaged or infected tissues that extravasate the vessels and attract immune cells to the site, and is characterized by responses such as redness, heat, and swelling that often comes with associated pain.²³ There are multiple proposed mechanisms behind chronic inflammatory pain, but in general it is believed that continuous sensitization induced by inflammatory mediators in primary afferent nociceptors causes long-lasting pain, or that certain neuroplastic changes in nociceptors after tissue damage leads to increased and prolonged sensitization of nociceptors, even with low-level exposure to pro-nociceptive inflammatory mediators.²³

INFLAMMATORY MOLECULAR MECHANISMS

More specifically, inflammatory components such as cytokines, ions, protons, amines, and growth factors are able to directly activate nociceptors which causes pain and hyperactive reaction to less intense stimuli such as a brush or light touch (allodynia) or increased pain sensation from a less painful stimuli (hyperalgesia).²⁴ Examples of endogenous mediators that are known to be involved in inflammation and nociception include prostaglandin E2 (PGE2), serotonin [5-hydroxytryptamine (5-HT)], ATP, histamine, proton and bradykinin (BK).²⁵ Of these mediators, PGE2, BK, proton, and 5-HT have been shown in earlier studies to possess excitatory roles on cutaneous nociceptors, with longer-term effects being achieved in high concentration (10^{-5} mol/L) combinations.²⁶⁻³⁰ Similarly, multiple studies have found ionotropic 5-HT₃ (a serotonin receptor) to be directly responsible for inflammatory pain.³¹⁻³³ Indeed, an experiment on 5-HT₃ gene knockout mice found intact acute pain responses, but decreases persistent pain responses.^{31,33}

Tissue acidosis, which denotes a tissue pH reduced to 5.4, is a common occurrence during periods of inflammation.³⁴ According to various murine models, higher local proton concentrations in inflamed tissues sensitize nociceptors and cause pain.²³ The mechanism behind this observation is likely that acidic solutions induce a cation conductance in a subset of dorsal root ganglion (DRG) nociceptive neurons, which occurs as a result of direct activation of proton-gated ion channels and proton-sensing GPCRs.^{23,35,36,84} Notable proton-gated ion channels that responsible for generating pain include those of the acid-sensing ion channels (ASICs) family, which includes

ASIC1a, ASIC1b, ASIC2a, ASIC2b, ASIC3, ASIC4, and ASIC5, and are expressed in the central and peripheral nervous systems.³⁷⁻³⁹ Of these channels, ASIC3 is the most sensitive to protons, and is expressed predominantly in muscle nociceptors.^{40,41} Due to its involvement with various inflammatory mediators (5-HT, BK, arachidonic acid, hypertonicity, and nitric oxide), this channel is also considered to be a sensor of acidic and primary inflammatory pain.⁴²⁻⁴⁶ Significant proton-sensing GPCRs include those of the OGR1 family, which are widely expressed in neuronal and non-neuronal tissues.⁴⁷ Although the evidence on their role in inflammatory pain is limited, it is known that around 75% to 82% of ORG1 GPCRs are present within DRG neurons responsible for nociception, and that one of the ORG1 family members, T-cell death-associated gene 8 (TDAG8) shows increased expression in complete Freund's adjuvant-induced inflammation and modulates pain through its action on transient receptor potential/vanilloid receptor subtype 1 (TRPV1).²³

The specific mechanism by which endogenous inflammatory mediators induce chronic pain in nociceptors occurs through peripheral sensitization, which involves inflammatory mediators binding to G-protein coupled receptors (GPCRs) to activate kinases A and C to then phosphorylate receptors and increase their expression, thereby enhancing the sensitivity of primary nociceptors by acting on ion channels to alter ion permeability and induce receptor potential.²³ Neurotransmitter release then activates intracellular kinases, leading to an abrupt activity-dependent increase in responsiveness and excitability of dorsal horn neurons, which is known as central sensitization.²³ After central sensitization, a noxious stimuli is no longer required in order to produce pain, resulting in chronic symptoms.²³

NITRIC OXIDE MECHANISM

The most relevant and abundantly studied chronic inflammatory pain mechanism for ESWT is that which proceeds through nitric oxide (NO) and its effect on the immune response to noxious stimuli. NO is a small gaseous molecule with a short half-life of a few seconds.⁴⁸ The molecule is able to easily permeate cell membranes, and thus cannot be stored in vesicles or secreted in a controlled fashion.⁴⁸ Instead, NO is produced from L-arginine by the activity of nitric oxide synthase (NOS) enzymes.⁴⁸ With regard to function, NO is an inter- and intracellular messenger that acts in the tissues, modulating sensory and spinal neuron excitability and contributing to different pain states.^{49,50} The effects of NO activity can be either harmful or beneficial, depending on the NOS isoform, concentration, chemical environment, chemical behavior, and stimulus required for activation.⁵¹ The two main isoforms of NOS are inducible NOS (iNOS), which is induced in cells after infection, trauma, or injury, and constitutive NOS (cNOS), which is continuously active in cells.⁵¹ Although there is only one type of iNOS, cNOS comes in three types: brain NOS (bNOS), neuronal NOS (nNOS), and endothelial NOS (eNOS).⁵¹ cNOS is believed to be the beneficial form of NOS that contributes to healing and is dependent on calcium

Table 1. Clinical Outcomes from Selected Extracorporeal Shockwave Therapy Studies for Tendinopathies and Carpal Tunnel Syndrome

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
Shoulder Tendinopathies									
(Xue et al. 2024) ¹	Systematic review and meta-analysis	16 randomized controlled trials (n = 1093) of patients with rotator cuff tendinopathy were included	Patients receiving ESWT	Mixed	Placebo ESWT treatment	- Primary outcome of pain (VAS), - Secondary outcomes of function (CMS) range of motion, University of California Los Angeles score, American Shoulder and Elbow Surgeons form, and Total effective rate (TER)	Not reported	There was a statistically significant difference in pain reduction between the ESWT group and control group; (SMD = -1.94, 95% CI -2.47, -1.41, P < 0.00001)	No serious adverse events were reported
(Brindisno et al. 2024) ²	Systematic review and meta-analysis	21 random controlled trials of patients with rotator cuff calcific tendinopathy	Patients receiving high-energy ESWT and low-energy ESWT	Both	Patients receiving sham-ESWT treatment	Pain and function	Baseline, 24 weeks	- Clinically significant difference between treatment and control groups in pain and function at 24 weeks; p < 0.00001 - High-energy ESWT was statistically and clinically superior in pain and function at <24 weeks; p < 0.002 - RSWT and FSWT were equally effective at reducing pain, improving disability, and resorption rate - Calcific deposits were resolved at 12 weeks	No significant events were reported
(Kamonseki et al. 2024) ³	Systematic review and meta-analysis	9 studies (n = 543) were included of patients with noncalcific rotator cuff tendinopathy - Mean age was 50.73 years 254 women and 289 men	Patients receiving ESWT	Studies were mixed	Patients receiving sham-ESWT treatment	Pain intensity (VAS and NRS) and function (simple shoulder test, VAS, Disability of the Arm, and Shoulder and Hand questionnaire)	Baseline, short-term, intermediate term, and long-term	- ESWT was superior to control group in effect on pain intensity at short-term follow-up (P = 0.04) - ESWT was not significantly superior to control group in improving pain intensity or function at intermediate and long-term follow-ups	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
								(P > 0.05)	
(Ebadi et al. 2023) ⁴	Randomized controlled trial	Patients affected by painful rotator cuff tendinopathy	Patients receiving ESWT (2000 pulse energy, 5 Hz) N = 17	Radial	Comparison to pre-treatment values	Pain (VAS), and Quick-DASH questionnaire	Baseline, 2 weeks, and 12 weeks post-treatment	• ESWT reduced patient pain by a statistically significant margin (p < 0.05) for VAS	No significant events were reported
(Fatima et al. 2022) ⁵	Randomized trial	• 42 patients affected by calcific tendinopathies • Patients aged between 30 and 65	Patients receiving ESWT at 2000 shockwaves of 0.32 mJ/mm ² and being subjected to routine physical therapy N = 21	Radial	Group assigned to routine physical therapy N = 21	Pain (NPRS), disability level (Constant-Murley Score) (CMS), and quality of life (Western Ontario rotator cuff index) (WORC)	Baseline, 6 weeks, and 12 weeks post-treatment	• Statistically significant differences in NPRS and CMS between the groups were observed (p < 0.05) • Intragroup differences showed statistically significant effects of ESWT treatment (p < 0.05)	No significant events were reported
(Kuo et al. 2022) ⁶	Randomized controlled trial	• Patients who had unilateral shoulder pain for more than 3 months	Patients receiving ESWT at 2 Hz (2000 shockwaves; 0.26 mJ/mm ²) once a week for 3 weeks	Radial	Included	• Primary outcome was pain (VAS) • Secondary outcomes were Constant scores, 36-Item Short-Form Health Survey, and range of motion	Baseline, 3 months	• Statistically significant improvements in VAS were observed (p < 0.05 during activity)	No significant events were reported
(Li et al. 2021) ⁷	Prospective randomized trial	• 46 patients affected by noncalcific rotator cuff tendinopathies	• Patients in Group A received 3000 shots at 0.09 ± 0.018 mJ/mm² of focused ESWT (N = 23) • Patients in Group B received 3000 shots at 0.09 ± 0.018 mJ/mm² of radial ESWT (N = 23)	Both	Compared to baseline values	Pain level and shoulder function assessed by NRS and Constant Murley Scale (CMS)	Baseline, 4 weeks, 12 weeks, 24 weeks, and 48 weeks	• Focused ESWT and radial ESWT are effective in patients with noncalcific rotator cuff tendinopathy • Focused ESWT resulted in significantly lower NRS pain scores at 24 weeks and 48 weeks after treatment when compared with radial ESWT (p < 0.001) • There were no significant differences between focused and radial ESWT groups before 24 weeks after	• In the focused ESWT group, 5 patients reported moderate pain, 1 patient reported syncope, and 2 patients reported skin redness • In the radial ESWT group, 3 patients reported moderate pain and 1 patient reported migraine

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
								treatment	
(Abo Al-Khair et al. 2021) ⁸	Randomized controlled trial	45 patients with calcific shoulder tendinopathy - Ages ranged from 30 to 68	- Patients receiving ESWT - Group 1 received 1500 shocks of focused ESWT - Group 2 received 2000 shocks of radial ESWT - Group 3 received both focused and radial ESWT	Both types, and mixed N = 15 (radial) N = 15 (focused) N = 15 (both)	Comparison to pre-treatment values	Shoulder pain, active range of motion, and shoulder function (SDQ)	Baseline, 1 week, and 3 months after treatment	- There was a significant improvement in shoulder pain, active range of motion, and shoulder function a 1 week after treatment and after 3 months follow-up - There was a significant reduction in calcification size according to sonographic analysis	No significant events were reported
(Louwerens et al. 2020) ⁹	Randomized controlled trial	82 patients with calcific tendinitis of the rotator cuff 56 female and 26 male - Mean age of 52.1 ± 9 years - Mean calcification size of 15.1 ± 4.7 mm	Patients receiving ESWT (2000 pulses at 0.35mJ/mm ²) in 4 sessions with 1-week intervals N = 41	Focused (piezoelectric)	Comparison to baseline values	Pain (VAS), Constant Murley Score (CMS), and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire	Baseline, 6 weeks, 3 months, 6 months, and 12 months after treatment	- At 6-week follow-up, ESWT showed statistically significant VAS improvement from baseline (p = 0.03) - At 3 month, 6 month, and 1 year follow-up, ESWT did not show statistically significant VAS improvements from baseline (p > 0.05) 67% of ESWT patients reported an improvement or a strong improvement in symptoms after 1 year	1 ESWT patient developed a frozen shoulder, but symptoms resolved during the study follow-up
(Efe et al. 2014) ¹⁰	10-year follow-up of a randomized placebo-controlled trial on	Patients with noncalcific supraspinatus tendinopathy	Patients receiving 6000 impulses at 0.11 mJ/mm ² of ESWT after local anesthesia	Not specified	6000 impulses of sham ESWT treatment after local anesthesia	Pain (VAS), and relative Constant score	Baseline, and 10 years after treatment	No significant changes in relative Constant scores, pain at rest, or pain during activity were found at the 10 year follow-up (p > 0.05)	No significant events were reported
Lateral Epicondylitis									
(Sen et al. 2024) ¹¹	Randomized clinical trial	Patients were age 18 or older and had pain,	Patients receiving ESWT set to 8 Hz and 1500 pulses/session at 0.18	Radial	Comparison to pre-treatment period	Tenderness, VAS, Q-DASH, and grip strength	Baseline, 3 weeks, and 12 weeks	ESWT treatment caused significant enhancements in VAS	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
		tenderness, and discomfort during physical exam	mj/mm ² N = 25					at the 3 rd and 12 th week follow-ups (p < 0.001)	
(Koru et al. 2023) ¹²	Randomized controlled study	90 patients diagnosed with chronic unilateral lateral epicondylitis - Mean age of 47.3 ± 7.95	Patients receiving 3 sessions of ESWT (1.8 bar, 10.0 Hz)	Radial	Comparison to pre-treatment values	Pain (VAS), quality of life (SF-36), function (PRTEQ and DASH questionnaire), and handgrip strength (Jamar dynamometer)	Baseline, at end of treatment, and one month post-treatment	VAS scores decreased by a statistically significant margin (p < 0.001) both during grip and at rest	No significant events were reported
(Kaplan et al. 2023) ¹³	Randomized sham-controlled trial	Patients with acute lateral epicondylitis aged 18 years and older	Patients receiving ESWT treatment for 3 sessions at 2-4 day intervals	Both	Sham-ESWT treatment	Pain and function, evaluated by patient-rated tennis elbow evaluation (PRTEE) score	Baseline, week 5, and week 13	- At weeks 5 and 13, all PRTEE scores were significantly improved in the focused ESWT and radial ESWT groups (p < 0.001), but not in the sham group (p > 0.05) - Focused ESWT was found to be more effective than radial ESWT for change of function scores from baseline to week 5 and week 13	No significant events were reported
(Liu et al. 2022) ¹⁴	Systematic review and network meta-analysis	40 randomized controlled trials on patients with chronic and acute lateral epicondylitis were included	Patients receiving ESWT treatment	Not specified for most studies	Sham-ESWT, subtherapeutic levels of ESWT, and wait and see	Pain, grip strength, DASH score, and PRTEE score	Baseline, short-term (< 3 months), and medium-term (> 3 months but ≤ 12 months)	ESWT was significantly efficacious in VAS improvement when compared to placebo (SMD, -0.57 [95% CI, -0.89 to -0.25])	No significant events were reported
(Karanasios et al 2021.) ¹⁵	Systematic review and meta-analysis	27 clinical trials (n = 1871) on patients with lateral elbow tendinopathy were included	Patients receiving ESWT	Not specified	Sham ESWT treatment	Pain intensity, grip strength, and elbow disability	Baseline, very short-term, short-term, and mid-term	- ESWT reduced pain intensity at mid-term follow-up (SMD: -1.21, 95% CI: -1.53, -0.80, P < 0.001) when compared to sham treatment - However, no clinically significant results were found between comparators in all	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
								outcomes and follow-up times • Low to moderate certainty of evidence	
(Guler et al. 2020) ¹⁶	Prospective randomized trial	• 40 patients with newly diagnosed lateral epicondylitis • 27 females and 13 males with a mean age of 42.6 ± 8.4 years	Patients receiving a 3 week treatment of ESWT once a week N = 20	Not specified	Comparison to pre-treatment values	Pain (VAS), hand grip strength, Roles and Maudsley scale (RMS), and quick DASH	Baseline, 4 weeks, and 8 weeks after treatment	ESWT achieved significant improvements in VAS, hand grip strength, and RMS after 4 and 8 weeks of treatment (p < 0.05)	No significant events were reported
(Yao et al. 2020) ¹⁷	Systematic review and meta-analysis	13 articles (n = 1035) on patients with lateral epicondylitis were included	Patients receiving ESWT N = 501	Not specified	Many studies utilized a placebo ESWT treatment	Pain (VAS), and grip strength	Baseline, and an unspecified amount of time after treatment	Pooled VAS scores were better in the ESWT groups (p = 0.0004)	No significant events were reported
(Ismael et al. 2020) ¹⁸	Randomized clinical trial	45 patients diagnosed with lateral epicondylitis	Patients receiving ESWT (1.6 bar, 16 Hz, 2000 shocks) for 3 sessions (1 week interval between sessions) N = 15	Not specified	Comparison to pre-treatment values	Pain (VAS), function (PRTEE), and grip strength	Baseline, 4 weeks, and 12 weeks after treatment	There was a statistically significant decrease of VAS and PRTEE scores at 4 weeks and 12 weeks of follow-up (p < 0.05)	Transient pain in the treated elbow (considered a guiltless adverse effect and the patient did not stop the therapy)
Achilles Tendinopathy									
(Charles et al. 2023) ¹⁹	Systematic review and meta-analysis	63 studies including patients affected by achilles tendinopathy, patellar tendinopathy, and plantar fasciitis with or without radiological confirmation	Patients receiving ESWT	Not specified	Patients receiving placebo-treatment	Pain intensity (VAS, NRS, or equivalent pain perception scale), and function (VISA-P, VISA-A, FFI, and AOFAS)	Baseline, short-term (≤ 3 months), mid-term (> 3 months - ≤ 6 months), and long term (≥ 12 months)	Concluded with low to moderate certainty of evidence that ESWT can reduce pain and function in the short term for achilles tendinopathy	No significant events were reported
(Stania et al. 2023) ²⁰	Systematic review and meta-analysis	6 studies on patients suffering from achilles tendinopathy were included N = 344	Patients receiving ESWT N = 157	Mixed	Patients receiving placebo ESWT N = 187	Pain (NRS), and severity of achilles tendinopathy (VISA-A questionnaire)	Short-term (< 6 months), and long-term (≥ 6 months)	No significant differences were found between ESWT and control groups	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
(Feeney et al. 2022) ²¹	Systematic review	• 7 randomized controlled trials on patients with achilles tendinopathy were included • Patient mean age range was 28.3 to 58.7	Patients receiving ESWT with exercise therapy	Mixed	Sham ESWT, wait and see, standard exercise therapy, or a mixture of the above	Pain (VAS), Likert scale, VISA-A score, AOFAS score, FIL, EQoL-5D, and health score	Baseline, and then within a range of 3 months to 16 months	• 3 studies reported no statistically significant improvement in outcomes with ESWT versus control • 4 studies found significant benefit in the ESWT groups compared with control; studies found significant VAS improvements, NRS improvements, and VISA-A improvements	No significant events were reported
(Paantjens et al. 2022) ²²	Systematic review of randomized controlled trials	3 randomized controlled trials on mid portion achilles tendinopathy and 4 randomized controlled trials on insertional achilles tendinopathy were included	Patients receiving ESWT at various energy levels with or without exercise therapy	Mixed	Exercise therapy without ESWT, or sham ESWT	Pain (VAS),	Baseline, short term (≤ 3 months), midterm (3 to 12 months), and long term (≥ 12 months)	• For mid portion achilles tendinopathy, moderate quality evidence was found for the overall effectiveness of ESWT compared to standard care • For insertional achilles tendinopathy, evidence of low quality indicated that, overall, ESWT provides no additional improvement from standard care	No significant events were reported
(Weiss et al. 2022) ²³	Systematic review	16 studies of patients with insertional and non-insertional achilles tendinopathy were included N = 505	Patients receiving ESWT	Not specified	Included for some studies	Pain (VAS) and function (VISA-A)	Baseline, and weighted mean follow-up was 8.1 months for insertional achilles tendinopathy, and 11.6 months for non-insertional achilles tendinopathy	VAS pain scores and VISA-A function scores showed improvement in both the insertional achilles tendinopathy and non-insertional achilles tendinopathy cohorts	No significant events were reported
(Gatz et al. 2021) ²⁴	Placebo-controlled	Patients with achilles	Patients receiving point and line-focused ESWT	Focused (line and point)	Placebo treatment	VISA-A	Baseline, 6 weeks, and 24 weeks	• There was a significant VISA-A	No significant events were

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
	randomized trial	tendinopathy	N = 21 (ESWT point) N = 24 (ESWT line)		N = 21			improvement over time for all treatment groups ($P < 0.001$) • ESWT point had the strongest VISA-A score improvement	reported
(Abdelkader et al. 2021) ²⁵	Randomized controlled trial	- Adult patients with unilateral non-insertional achilles tendinopathy who failed conservative treatment 22 men and 28 women aged 18-40	Patients receiving ESWT and exercise therapy N = 25	Not specified	Sham ESWT treatment and exercise therapy N = 25	Pain (VAS), function (VISA-A),	Baseline, 1 month, and 16 months after treatment	At both follow-up assessment points, the study group had significantly superior VAS and VISA-A scores that the control group ($p = 0.0001$)	No significant events were reported
(Mansur et al. 2021) ²⁶	Double-blinded randomized clinical trial	119 patients with insertional achilles tendinopathy	Patients receiving ESWT with eccentric exercises	Not specified	Patients receiving sham ESWT with eccentric exercises	Achilles function (VISA-A), pain (VAS), algometry, the Foot and Ankle Outcome Score, and the 12-Item Short Form Health Survey	Baseline, 24 weeks	- Both treatment and control groups showed improvement during the study period, but there were no statistically significant differences between them ($p > 0.05$) - There was a higher rate of failure (38.3%), but a lower rate of recurrence (17.0) in the treatment group than the control group	No significant events were reported
(El-Mallah et al. 2020) ²⁷	Prospective clinical trial	40 patients with chronic achilles tendinopathy	Patients receiving ESWT (1500 focused shots 0.21mJ/mm ² and 3000 radial shots 1.8mJ/mm ²) once a week for 4 consecutive weeks	Both	Comparison to pre-treatment values	Primary outcome was pain (VAS)	Baseline, 4 weeks, and 12 weeks after treatment	Highly significant decrease of pain at 4 and 12 weeks ($p < 0.001$)	No significant events were reported
Patellar Tendinopathy									
(Charles et al. 2023) ¹⁹	Systematic review and meta analysis	63 studies including patients affected by achilles tendinopathy,	Patients receiving ESWT	Not specified	Patients receiving placebo-treatment	Pain intensity (VAS, NRS, or equivalent pain perception scale), and function (VISA-P, VISA-A, FFI, and	Baseline, short-term (≤ 3 months), mid-term (> 3 months - ≤ 6 months), and long	Concluded with low to moderate certainty of evidence that ESWT can reduce pain and	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
		patellar tendinopathy, and plantar fasciitis with or without radiological confirmation				AOFAS)	term (≥ 12 months)	function in the short term for patellar tendinopathy	
(Krogh et al. 2021) ²⁸	Randomized double-blind placebo-controlled trial	36 athletes with patellar tendinopathy	Patients receiving 3 treatments of ESWT given at intervals of 14 days N = 18	Focused (electrohydraulic)	Patients receiving placebo treatment N = 18	Changes in pain while walking, at rest, and when the tendon was squeezed, reported by the NRS	Baseline, 2 weeks, 4 weeks, and 12 weeks after treatment	• ESWT was significantly more effective than placebo regarding pain while walking ($p = 0.011$) • There was no difference in pain at rest ($p = 0.404$) or when the tendon was squeezed ($p = 0.221$)	No significant events were reported
Greater Trochanteric Pain									
(Harding et al. 2024) ²⁹	Systematic review and meta-analysis	12 articles ($n = 1121$ subjects) were included, including 5 randomized controlled trials and 7 non-randomized controlled trials	Patients receiving ESWT	Not specified	Patients not receiving ESWT	Pain and function	Baseline and post-intervention	• Moderate quality evidence demonstrated no statistically significant improvements in pain and function when after ESWT when compared to control	No significant events were reported
De Quervain Tenosynovitis									
(Haghighat et al. 2021) ³⁰	Clinical trial	• 26 patients with diagnosed de Quervain tenosynovitis that were over the age of 18 • 10 males and 16 females • Mean age of 48.23 ± 14.45	Patients receiving ESWT with conservative treatment N = 13	Radial	Sham treatment with conservative treatment N = 13	Pain (VAS), disability (DASH), and hand grip strength	Baseline, 3 weeks, 6 weeks and 2 months after treatment	• VAS pain scored in the intervention group decreased significantly after the treatment ($P < 0.05$), whereas changes were insignificant in the sham group ($P > 0.05$) • Means of VAS scores were significantly lower in the intervention group after treatment as well at 3 and 6 weeks after treatment ($P < 0.05$)	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
Carpal Tunnel Syndrome									
(VONGVACHVASIN et al. 2023) ³¹	Single-blind randomized controlled trial	• 24 patients with moderate to severe carpal tunnel syndrome • Patients had a symptom duration of up to 36 months	Patients receiving ESWT (0.01 to 0.15 mJ/mm², a frequency of 4–5 Hz, and 1500 pulses per session once a week for a total of 3 sessions) in addition to conservative treatment N = 12	Focused	Patients receiving conservative treatment alone N = 12	Pain [Boston Carpal Tunnel Questionnaire (T-BCTQ)], a nerve conduction study, and ultrasonography of the median nerve cross-sectional area	Baseline, 3 weeks, and 6 weeks	There was a significant decrease in symptoms such as pain after 6 weeks , as reported by the BCTQ of symptom severity (p < 0.05)	No significant events were reported
(Menekseoglu et al. 2023) ³²	Placebo-controlled, double-blind clinical trial	37 patients with carpal tunnel syndrome	Patients receiving ESWT N = 27	Radial	Patients receiving sham ESWT N = 28	Pain (VAS), functionality, and electrophysiological measurements	Baseline and 1 month after treatment	There was a significant decrease in VAS pain score in the ESWT group (p < 0.001)	No significant events were reported
(Chen et al. 2022) ³³	Systematic review and meta-analysis	7 randomized controlled trials on patients (n = 376) with carpal tunnel syndrome	Patients receiving ESWT	Mixed	Sham ESWT or conservative therapy	Pain (VAS), and Boston Carpal Tunnel Syndrome Questionnaire (BCTQ)	Baseline, and then 4 to 14 weeks	ESWT groups showed significantly lower VAS pain scores at 4 weeks of follow-up (p = 0.03)	No significant events were reported
(Xie et al. 2022) ³⁴	Systematic review and meta-analysis	10 trials on patients (n = 433) with carpal tunnel syndrome	Patients receiving ESWT	Both	Sham ESWT, or conservative treatment, or another intervention	Pain (VAS), syndrome alleviation, and function	Baseline, and then either < 3 months or ≥ 3 months	• Radial ESWT group experienced significant effect on pain relief (p = 0.03) • Focused ESWT had no significant effect on pain relief (p > 0.05)	No significant events were reported
(Durmaz et al. 2022) ³⁵	Randomized controlled trial	72 patients diagnosed with carpal tunnel syndrome	Patients receiving ESWT	Radial	Patients receiving only a resting hand splint	Pain (VAS), the Boston Symptom Severity Scale, the Boston Functional Status Scale, and handgrip strength	Baseline, 1 week, and 12 weeks after treatment	Compared to baseline, VAS pain scores improved significantly in the ESWT group at 1 week and 12 weeks (p < 0.05)	Some patients reported pain
(Habibzadeh et al. 2022) ³⁵	Randomized clinical trial	60 patients with carpal tunnel syndrome	Patients receiving ESWT (1500 shocks on both the carpal tunnel and median nerve pathways; either pointing or sweeping shock wave therapy) and conventional physiotherapy for 10 sessions N = 40	Radial	Patients receiving conventional physiotherapy for 10 sessions N = 20	Pain (VAS) and paresthesia intensity, sensory and motor distal latency	Baseline, 1 week, and 4 weeks after the end of treatment	Compared to the control group, significantly greater improvement in VAS pain scores was experienced in ESWT groups after 4 weeks (p < 0.001)	Transient pain and redness of the skin were reported after application of shockwave

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
(Xu et al. 2020) ³⁶	Randomized controlled trial	30 patients with carpal tunnel syndrome	Patients receiving 3 ESWT (1000 shocks, 1.5 bar, 6 Hz) sessions once per week for 3 consecutive weeks	Not specified	Comparison to baseline	Pain and paresthesia (VAS), Boston Carpal Tunnel Questionnaire (BQ), and a nerve conduction study	Baseline, 3 weeks, 9 weeks, and 12 weeks after the start of treatment	There were significant improvements in VAS pain scores in the ESWT group at the 3 week, 9 week, and 12 week follow-ups ($p < 0.05$)	One patient complained of recurrent transient wrist pain after 12 weeks
(Kim et al. 2019) ³⁷	Systematic review and meta-analysis	6 randomized controlled trials on patients (n.= 281) with mild to moderate carpal tunnel syndrome	Patients receiving ESWT	Mixed	Patients receiving control treatments	Symptoms (such as pain), functional outcomes, and electrophysiologic parameters	Baseline, and then 12 to 24 weeks	ESWT showed greater improvement in symptoms than the control group ($p < 0.006$)	No significant events were reported
(Swilam et al. 2018) ³⁸	Randomized clinical trial	62 patients with carpal tunnel syndrome	Patients receiving 2 sessions with a 1-week interval of ESWT (2500 shocks, 10 Hz, 2 bar) N = 31	Not specified	Comparison to baseline	Pain (VAS), DX studies, and the Boston Carpal Tunnel Questionnaire (BCTQ)	Baseline, 2 weeks, and 4 weeks	Significant improvement ($p < 0.05$) in VAS was observed in the ESWT group	No significant events were reported
(Atthakomol et al. 2018) ³⁹	Randomized controlled trial	25 patients with mild to moderately severe carpal tunnel syndrome	Patients receiving a single dose of ESWT N = 13	Radial	Comparison to baseline	Pain (VAS), Boston self-assessment questionnaire (BQ), and electrodiagnostic parameters	Baseline, 1 week, 4 weeks, 12 weeks, and 24 weeks after treatment	When compared to baseline, there was significant reduction of VAS and functional score in the ESWT group at weeks 12 and 24 ($p = 0.022$ and $p = 0.0075$ respectively)	No significant events were reported
(Raissi et al. 2017) ⁴⁰	Randomized clinical trial	40 patients with mild to moderate carpal tunnel syndrome	Patients receiving ESWT (1000 shocks at a pressure of 1.5 Bar and a rate of 6 pulses/sec) and wrist splint N = 20	Radial	Patients receiving a wrist splint N = 20	Pain (VAS), function (QuickDASH), and nerve conduction studies	Baseline, 3 weeks, 8 weeks and 12 weeks	Significant VAS reductions were observed in the ESWT group when compared to control at 3 weeks, 8 weeks, and 12 weeks ($p < 0.001$)	One patient complained of transient wrist pain after 12 weeks
(Karatas et al. 2017) ⁴¹	Sham controlled double blinded randomized study	49 patients with carpal tunnel syndrome	Patients receiving ESWT (1 session per week for 3 weeks) N = 29	Not specified	Patients receiving sham ESWT (1 session per week for 3 weeks) N = 20	Boston Scale (symptom severity and functional capacity), Visual Analogue Scale (VAS) for pain and paresthesia assessment	Baseline, and at the end of the first week, first month and third month after the last ESWT treatment	• Significant improvements in VAS were observed in both groups ($p < 0.05$) • There were no statistically significant differences between treatment and	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
								control groups ($p > 0.05$)	
(Ke et al. 2016) ⁴²	Randomized, single-blind, placebo-controlled trial	69 patients with mild to moderate carpal tunnel syndrome	Patients receiving ESWT (3 sessions or 1 session) N = 66	Radial	Patients receiving sham ESWT N = 33	Primary outcome was Boston Carpal Tunnel Syndrome Questionnaire (BCTQ) points	Baseline, 4 weeks, 10 weeks, and 14 weeks	Compared to the control group, the 3 session ESWT group experienced significant pain and disability reductions after 14 weeks ($p < 0.05$)	No significant events were reported

Table 2. Clinical Outcomes from Selected Extracorporeal Shockwave Therapy Studies for Myofascial Pain, Plantar Fasciitis, and Fibromyalgia

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
General Myofascial Pain									
(Avendaño-López et al. 2024) ⁴³	Systematic review and meta-analysis of randomized clinical trials	• 27 trials (N = 1377) on patients with myofascial pain syndrome of the cervical, shoulder, leg/foot, and lumbar spine regions • 802 women and 575 men • Age ranged from 18 to 70 years	Patients receiving ESWT N = 595	Mixed	Patients receiving sham ESWT or control treatments N = 570	Pain (VAS and Pain Pressure Threshold), range of motion, and quality of life (SF-36)	Baseline, immediately postintervention, and anywhere from 3 to 24 weeks after treatment for the studies that reported this metric	ESWT was significantly effective in relieving pain when compared to the control groups (MD = -1.7 cm; 95% CI = -2.2 to -1.1) with high heterogeneity ($I^2 = 77\%$, $P < 0.001$)	No significant events were reported
(Scaturro et al. 2024) ⁴⁴	Clinical trial	• 54 patients with myofascial pain syndrome in the cervical spine, lumbar spine, and shoulder muscles • Mean age of 48.76 ± 9.54 years • 24 men and 30 women	Patients receiving 5 sessions of ESWT on a weekly basis N = 27	Focused	Comparison to baseline	Pressure Pain Threshold, NRS, and Short Form-36 (SF-36)	At enrollment, after the end of rehabilitation treatment, and 30 days after treatment	• Statistically significant improvements in NRS and pain pressure threshold after the end of rehabilitation treatment ($p \leq 0.05$) • The were no statistically significant improvements 30 days after the end of treatment	No significant events were reported
(Candeniz et al. 2023) ⁴⁵	Clinical trial	42 female patients diagnosed with myofascial pain syndrome	Patients receiving 2 sessions of ESWT per week for 6 sessions ESWT in addition to conservative treatment N = 14	Not specified	Patients receiving conservative treatment alone N = 14	Pain (VAS), pain pressure threshold (PPT), cervical joint range of motion, Neck Outcome Score (NOOS), and Hospital Anxiety and Depression Scale (HADS)	Baseline, 3 weeks after treatment	The ESWT intervention was significantly effective in reducing the severity of activity pain when compared to control ($p < 0.05$)	No significant events were reported
(Suputtitada et al. 2022) ⁴⁶	Randomized controlled trial	• 60 patients suffering from myofascial trigger points • For the radial ESWT patient group, mean age was 23.05 ± 1.02	Patients receiving 3 treatment sessions, one treatment session per week N = 30	Radial	Comparison to baseline	Primary outcome was pain severity measured by the VAS score	Baseline, 15-30 minutes after the first treatment, before the second treatment (1 week after baseline measurement), and one week after the third treatment	Statistically significant improvements in VAS when comparing baseline to both after the third treatment and before the second treatment	Pain and redness of the skin were noted in a few cases, but the patients did not drop out of the study
(Tognolo et	Randomized	26 patients	Patients receiving 3	Focused	Patients	Foot and Ankle Outcome Score	Baseline, 1 month,	Statistically significant	No

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
al. 2022) ⁴⁷	clinical trial	suffering from plantar fasciitis	sessions of ESWT on myofascial points		receiving 3 sessions of ESWT on the medial calcaneal tubercle	(FAOS) and the Italian Foot Functional Index (17-iffi)	and 4 months	improvement in FAOS and 17-iffi scores was confirmed at the 1 month and 4 month follow-ups with earlier improvement being experienced by the treatment group ($p < 0.05$)	significant events were reported
(Hyun et al. 2021) ⁴⁸	Meta-analysis of randomized controlled trials	11 randomized controlled trials on patients with myofascial pain syndrome of the neck and shoulder	Patients receiving ESWT	Mixed	Sham ESWT or a different therapy (varied by study)	Pain intensity, pressure pain threshold, and neck disability	Baseline, and then a mix of anywhere from 2 weeks to 4 weeks in particular studies	• ESWT had a large effect on improving pain intensity (SMD = 0.67, 95% CI: 0.11 to 1.23, $P = 0.02$) • ESWT had a positive effect on pressure pain threshold (SMD = 1.19, 95% CI: 0.27 to 12.12, $P = 0.01$) • Focused ESWT shows significant improvement in pain relief when compared to other types of ESWT	• 2 patients had transient sensitivity in one trial, but did not drop out
(Rahbar et al. 2021) ⁴⁹	Single-blinded randomized clinical trial	72 patients with neck and upper back myofascial pain	Patients receiving ESWT N = 24	Not specified	Patients performing self-stretch-exercises N = 24	Pain intensity (VAS), pain pressure threshold (algometer), and disability (neck disability index)	Baseline, 1 week, and post-intervention at week 4 after treatment	• ESWT improved VAS ($p = 0.083$) when compared to control at week 1 • After week 4, additional improvements in VAS were achieved	No significant events were reported
(Denizli et al. 2020) ⁵⁰	Clinical trial	32 patients with myofascial pain syndrome aged between 18 and 60	Patients receiving ESWT (700 pulse, 4 Hz, 1.5 bar, 5 min) N = 18	Not specified	Sham ESWT treatment N = 14	Pain (VAS), functional status by Neck Pain and Disability (NPDI), and quality of life (Nottingham Health Profile)	Baseline and after treatment	Statistically significant improvements in VAS were observed in the treatment group alone	No significant events were reported
(Kamel et al. 2020) ⁵¹	Randomized controlled trial	46 patients with cervical myofascial pain following neck dissection surgery	Patients receiving ESWT (0.25mL/mm ² , 1000 shocks) once a week for 4 weeks with a topical NSAID	Focused	Patients receiving only topical NSAID	Pain (VAS), and range of motion	Baseline, 2 weeks, and 4 weeks after treatment	The ESWT group had significant improvement in VAS scores at all follow-up time points when compared with the control ($p < 0.001$)	No significant events were reported
(Zhang et al. 2020) ⁵²	Systematic review and meta-analysis	10 articles (n = 477 on patients with myofascial pain syndrome of the trapezius were included)	• Patients receiving ESWT on myofascial trigger points • Frequency varied from 1 session per week to 3 sessions per week • Duration of treatment	Mixed	Patients receiving sham ESWT or conservative treatment	Primary pain outcome reported was VAS and NRPS	Follow-up time ranged from none to 12 weeks	ESWT exhibited significant improvement in pain reduction compared with sham ESWT and ultrasound treatment, but there was no significant effect when compared	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
			lasted from 2 weeks to 4 weeks					with conventional treatments	
(Aktürk et al. 2018) ⁵³	Randomized, sham-controlled study	• 60 patients with myofascial pain syndrome aged 18-60 years • 40 females and 20 males • Mean age of 34.85 ± 9.25	Patients receiving ESWT (1.6-3.0 bar, 200-400 shocks/trigger point, total of 2000-3000 shock/session) for 4 sessions and 3 day intervals	Not specified	Patients receiving 4 sessions of sham ESWT	Pain pressure threshold, pain score (VAS), SF-36, and Hospital Anxiety and Depression Scale	Baseline, and 6 weeks after treatment	Statistically significant improvements were experienced in the ESWT group in VAS, whereas none were experienced in the control group (P <0.01)	No significant events were reported
Plantar Fasciitis									
(Simental-Mendía et al. 2024) ⁵⁴	Systematic review and meta-analysis of randomized controlled trials	14 studies (n = 867) on patients with plantar fasciitis were included	Patients receiving ESWT N = 437	Mixed	Patients treated with nonsurgical therapy N = 430	Pain (VAS), plantar fascia thickness	Baseline, and follow-up anywhere from 1 to 6 months after treatment	No significant improvement in pain was observed (p = 0.06)	No significant events were reported
(Pabón-Carrasco et al. 2024) ⁵⁵	Randomized clinical trial	• 142 Patients with plantar fasciitis • Mean age was 50.1 ± 10.3 • Mean BMI of 27.1 ± 2.4 • 44.1% women and 55.9% men	Patients receiving ESWT (2000 pulses, 5 Hz at 0.20mJ/mm ²)	Radial	Comparison to baseline	Pain (VAS), foot posture index (FPI), EQ-5D, and fascia thickness	Baseline, 2 nd session, 3 rd session, 4 th session, 5 th session, and at 12 weeks	• There was statistically significant improvement in VAS for the ESWT when compared with baseline (p = 0.001)	No significant events were reported
(Dede et al. 2024) ⁵⁶	Randomized trial	55 patients with plantar fasciitis	Patients receiving 3 sessions of ESWT to the plantar fascia	Radial	Comparison to baseline	Pain (VAS) and foot function index	Baseline, 1 week, and 4 weeks	There was significant improvement in VAS in the 4-week follow-up from baseline (p < 0.01)	No significant events were reported
(Charles et al. 2023) ¹⁹	Systematic review and meta-analysis	63 studies including patients affected by achilles tendinopathy, patellar tendinopathy, and plantar fasciitis with or without radiological confirmation	Patients receiving ESWT	Not specified	Patients receiving placebo-treatment	Pain intensity (VAS, NRS, or equivalent pain perception scale), and function (VISA-P, VISA-A, FFI, and AOFAS)	Baseline, short-term (≤ 3 months), mid-term (> 3 months - ≤ 6 months), and long-term (≥ 12 months)	Concluded with high certainty of evidence that ESWT has a large effect on improving function and reducing pain in the short-term, mid-term, and long-term for plantar fasciitis	No significant events were reported
(Al-Siyabi et al. 2022) ⁵⁷	Systematic review and	7 studies (n = 369) on patients with	Patients receiving ESWT	Majority of studies	Patients receiving no	Morning and activity pain (VAS), functional impairment,	Baseline, immediately after	Statistically significant improvement of pain	No significant

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
	meta-analysis	plantar fasciitis were included		used radial	treatment or another interventional therapy	the American Orthopedic Foot and Ankle Society (AOFAS) scale score, fascial thickness, primary efficacy success rate, activity limitations, pain intensity, and satisfaction	treatment, and 4 weeks after treatment	during activity was observed for the ESWT group (p = 0.005)	events were reported
Fibromyalgia									
(Sanzo et al. 2024) ⁵⁸	Multidisciplinary randomized controlled trial	13 Patients with fibromyalgia aged 18-60	Patients receiving 5 treatments of ESWT (1 week apart over a 5 week period, 500 shocks, 1.5 bar, 15 Hz, and then 1000 shocks at 2 bar, Hz, and then finally 500 shocks, 1.5 bar, and 15 Hz) N = 7	Radial	Patients receiving sham ESWT N = 6	Pain (VAS), Quantitative sensory testing (QST), Beighton Scoring Screen (BSS), Pain Catastrophizing Scale (PCS), blood biomarker (Interleukin (IL)-6 and IL-10), and brain fMRI	Before treatment and after treatment	- There were no statistically significant differences in VAS between the ESWT and control (p = 0.61) - VAS scores had clinically significant changes and improved pain scores in the ESWT group	No significant events were reported

Table 3. Clinical Outcomes from Selected Extracorporeal Shockwave Therapy Studies for Bone Disorders

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
Knee Osteoarthritis									
(Liao et al. 2024) ⁵⁹	Systematic review	24 studies (n = 888) on patients with knee osteoarthritis were included	Patients receiving ESWT	Mixed	Sham ESWT or conservative treatment	Primary outcome was pain (VAS)	Baseline, and then between 1 week and 12 months after treatment	- Study concluded that ESWT was effective for knee osteoarthritis when compared with sham ESWT ESWT was not effective for patients with severe knee osteoarthritis	No significant events were reported
(Silva et al. 2023) ⁶⁰	Systematic review with meta-analysis and grade recommendations	12 studies (n = 734) on patients with knee osteoarthritis	Patients receiving ESWT N = 403	Not specified	Sham ESWT N = 331	Pain and function	Short-term, medium-term, and long-term	Compared to the control, ESWT was favored in short-term, medium-term, and long-term for pain (P < 0.01)	No significant events were reported
(Arslan et al. 2022) ⁶¹	Clinical trial	51 Patients diagnosed with stage 2 or stage 3 primary knee osteoarthritis	Patients receiving ESWT (2.0 bar, 0.25 mJ/mm ² , 10 beats/sec) once a week for 3 sessions N = 26	Radial	Comparison to baseline	Pain (VAS), Western Ontario McMaster Universities Osteoarthritis index (WOMAC), joint ROM measurements, and the Timed "Up & Go" (TUG) test	Baseline, 10 days, and 21 days after the first treatment	The ESWT group had statistically significant improvements in VAS at the 10 and 21-day mark when compared to pre-treatment values (p < 0.05)	No significant events were reported
(Ho et al. 2022) ⁶²	Randomized controlled trial	36 patients with knee osteoarthritis	Patients receiving ESWT for 3 weeks and physical therapy	Focused	Patients receiving sham ESWT and physical therapy	Pain (VAS), and physical function [Western Ontario McMaster Universities Osteoarthritis index (WOMAC)]	Before treatment, at the 3 rd week of treatment, and 1 week after the end of treatment	- The ESWT group had significant improvement in WOMAC pain score (p < 0.001) and VAS pain score (p < 0.001) at 1 week after the end of treatment - When compared to the control group, ESWT had a statistically significant difference in improvement in WOMAC pain scores (p = 0.001) and VAS pain scores (p = 0.027)	No significant events were reported
(Zhang et al. 2021) ⁶³	Randomized controlled trial	89 patients diagnosed with knee osteoarthritis	- Patients receiving 1 of 4 ESWT shock intensity treatments in 4 sessions, each one week apart [(0.12 mJ/mm², lower density, or 0.24 mJ/mm², higher density) and shock number (2,000 impulses or 4,000 impulses)] - N = 75	Radial	Patients receiving placebo control N = 14	Pain (VAS), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score	Baseline, after each session, and 4 weeks after treatment	- There were significant decreases (p < 0.001) over time in VAS-pain scores for all active treatments, with the greatest change at the 4-week follow-up Higher density ESWT was significantly more effective than the lower density and control treatments in reducing VAS-pain scores (p < 0.001)	Minor skin reddening for a brief period following treatment

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
(Avendaño-Coy et al. 2020) ⁶⁴	Systematic review and meta-analysis of randomized clinical trials	14 studies (n = 782) on patients with knee osteoarthritis	Patients receiving ESWT	Mixed	Sham ESWT, no intervention, sham intervention, or other conservative treatments	Pain (VAS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), range of motion, and walking test	Baseline, and then between 1 week and 12 months after treatment	Moderate quality evidence shows that ESWT is more effective on VAS pain when compared with control groups or other interventions [mean difference = 1.7 cm; confidence interval 95%: 1.1–2.3]	Minor pain, skin reddening, swelling, and burning sensation
Fractures and Non-Union									
(Garcia et al. 2024) ⁶⁵	Systematic review and meta-analysis and meta-regression	8 studies on patients with bone fractures, osteonecrosis, nonunion or delayed union, and bone edema	Patients receiving ESWT	Not specified	Patients receiving surgery, or a specific drug treatment	Pain (VAS), function, size of lesion, and non-union rate	Baseline, 3 months, 6 months, 12 months, and 24 months	• When compared to the control group at 3 months, ESWT had favorable results on pain from fractures, bone edema and femoral head necrosis (p = 0.01) • At 6 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control (p = 0.004) • At 12 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control (p = 0.04) • At 24 months, no statistically significant difference was found between the shockwave group and the control group (p = 0.16)	No significant events were reported
Osteonecrosis of Femoral Head									
(Garcia et al. 2024) ⁶⁵	Systematic review and meta-analysis and meta-regression	8 studies on patients with bone fractures, osteonecrosis, nonunion or delayed union, and bone edema	Patients receiving ESWT	Not specified	Patients receiving surgery, or a specific drug treatment	Pain (VAS), function, size of lesion, and non-union rate	Baseline, 3 months, 6 months, 12 months, and 24 months	• When compared to the control group at 3 months, ESWT had favorable results on pain from fractures, bone edema and femoral head necrosis (p = 0.01) • At 6 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control (p = 0.004) • At 12 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control (p = 0.04)	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
								At 24 months, no statistically significant difference was found between the shockwave group and the control group ($p = 0.16$)	
(Abbas et al. 2023) ⁶⁶	Systematic review	13 articles on patients with osteonecrosis of femoral head were included	Patients receiving high energy, moderate energy, and low energy flux densities of ESWT	Not specified	Not specified	Pain, function, and disease progression	Not specified	High energy flux densities of ESWT were found to be the most effective in the earlier course of the disease compared to later stages with regard to pain relief	No significant events were reported
Bone Edema									
(Garcia et al. 2024) ⁶⁵	Systematic review and meta-analysis and meta-regression	8 studies on patients with bone fractures, osteonecrosis, nonunion or delayed union, and bone edema	Patients receiving ESWT	Not specified	Patients receiving surgery, or a specific drug treatment	Pain (VAS), function, size of lesion, and non-union rate	Baseline, 3 months, 6 months, 12 months, and 24 months	- When compared to the control group at 3 months, ESWT had favorable results on pain from fractures, bone edema and femoral head necrosis ($p = 0.01$) - At 6 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control ($p = 0.004$) - At 12 months, ESWT had significant effect on pain from fractures, bone edema and femoral head necrosis over control ($p = 0.04$) - At 24 months, no statistically significant difference was found between the shockwave group and the control group ($p = 0.16$)	No significant events were reported
Coccydynia									
(Ahadi et al. 2022) ⁶⁷	Randomized clinical trial	34 patients with coccydynia 1 male and 16 females (within treatment group)	Patients receiving ESWT (2000 shockwaves, 3-4 bar, 5 Hz) for 3 weekly sessions N = 17	Radial	Comparison to baseline	Pain (VAS), and Short-Form Health Survey and Dallas Pain Questionnaire	Baseline, 1 week, 1 month, 2 months, and 6 months after the intervention	VAS score significantly decreased in all follow-up assessments after ESWT ($p < 0.001$)	No significant events were reported

Table 4. Clinical Outcomes from Selected Extracorporeal Shockwave Therapy Studies for Back Pain

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
Low Back Pain									
(Back et al. 2024) ⁶⁸	Randomized placebo-controlled triple-blind trial	81 patients with chronic non-specific low back pain aged 18-80 with pain for ≥ 3 months and pain intensity ≥ 3	Patients receiving ESWT (2000 discharged at 100 mJ and 5 Hz) with either a concave tip or a convex tip	Radial	Placebo treatment	Pain intensity, pressure pain threshold, temporal summation of pain, and functional performance	Baseline and post-intervention	• Post-intervention pain intensity in the concave tip group was significantly improved from the placebo group ($p < 0.01$) • Post-intervention pressure pain threshold for the concave tip group was significantly improved when compared to placebo ($p < 0.01$) • The concave tip group experienced statistically significant improvements over the convex tip group with regard to pressure pain threshold ($p < 0.05$)	No significant events were reported
(Liu et al. 2023) ⁶⁹	Systematic review and meta-analysis	12 randomized controlled trials (n = 632) on patients with chronic low back pain were included	Patients receiving ESWT N = 318	Mixed	Patients receiving physical exercise, physiotherapy, medicine or other similar interventions N = 314	Pain (VAS), function (ODI dysfunction index), and mental health [SF-36, Patient Health Questionnaire 9 (PHQ-9) and Beck Depression Index (BDI)]	Baseline, 4 weeks and 12 weeks	The ESWT group reported significantly more pain relief than the control group at 4 weeks ($p < 0.001$) and 12 weeks ($p < 0.001$)	No significant events were reported
(Wu et al. 2023) ⁷⁰	Systematic review and meta-analysis	22 studies (n = 1749) on patients with low back pain were included	Patients receiving ESWT N = 881	Not specified	Patients receiving sham ESWT, conservative treatment, or another intervention N = 868	Primary outcomes were pain (VAS), dysfunction (range of motion and ODI), and psychological health (Beck depression inventory)	Baseline and 3 months after treatment	The ESWT group had significantly lower scores in VAS for pain ($p < 0.00001$)	2 studies reported pain during treatment and local swelling on the day of treatment
(Li et al. 2022) ⁷¹	Systematic review and meta-analysis	13 randomized controlled trials on patients with low back pain	Patients receiving ESWT	Mixed	Patients receiving sham ESWT, conservative treatment, or another intervention	Pain (VAS or NRS), function (ODI)	Baseline, 1 month and 3 months	• The ESWT group showed lower pain intensity at month 1 ($p < 0.05$) and month 3 ($p < 0.05$) • There was no statistically significant	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
		were included						pain difference between ESWT and control groups at month 3 ($p > 0.05$)	
(Sun et al. 2022) ⁷²	Randomized controlled trial	69 patients with chronic low back pain	Patients receiving 6 sessions of low intensity ESWT (4000 pulses at 0.03 mJ/mm²) during a 2 week treatment period (3 sessions per week) or 2 sessions of medium intensity ESWT (4000 pulses at 0.09 mJ/mm²) with 1 session per week in a 2 week treatment period	Not specified	Comparison to baseline	Pain (VAS) at rest and at movement, function (ODI), and the Hospital Anxiety and Depression Scale (HADS)	Baseline, 2 weeks, 4 weeks, 6 weeks, and 3 months after randomization	- Both low intensity and medium intensity ESWT provided significant improvement in VAS scores at each follow-up time point ($p < 0.05$) - Between group comparison indicated that low intensity ESWT had better VAS improvement than medium intensity ESWT at 2 weeks, 4 weeks, and 6 weeks after randomization ($p < 0.05$)	No ESWT-related side effects such as hematoma, bruise, pain in the treated area, or any other adverse events that required intervention occurred in any group
(Yue et al. 2021) ⁷³	Systematic review and meta-analysis of randomized controlled trials	10 randomized controlled trials on patients ($n = 455$) with chronic low back pain (≥ 3 months) - Ages ranged from 29.2- 55.8	Patients receiving ESWT alone or with other therapies	Not specified	Patients receiving sham ESWT or other active therapies	Pain intensity (VAS and NRS) and disability status (ODI)	Baseline, 1 month, and 3 months	Compared with control the ESWT group showed lower pain intensity at month 1 ($p < 0.01$)	No significant events were reported
(Lange et al. 2021) ⁷⁴	Randomized controlled trial	63 Patients with acute lumbar back pain	Patients receiving ESWT (400 impulses 8 Hz at 0.28 mJ/mm²) N = 27	Radial	Patients receiving sham ESWT placebo treatment N= 26	- Primary outcome was acute lumbar back pain (VAS) - Secondary outcomes were the Oswestry disability index (ODI), Roland and Morris Disability Questionnaire (RDQ), EuroQol EQ-5D-3L, and the Beck Depression Index (BDI-II)	Baseline, 1 week, 2 weeks, 3 weeks, 4 weeks, 6 weeks 8 weeks, and 12 weeks	- Both groups showed significant improvement in VAS at the final follow-up ($p < 0.001$) VAS declined by 86.4% in the control group and by 60.7% in the intervention group	No significant events were reported
(Çelik et al. 2020) ⁷⁵	Prospective randomized placebo-	45 patients with chronic low back	Patients receiving ESWT N = 25	Not specified	Patients receiving placebo ESWT	Pain (NRS), function (ODI), Hospital Anxiety and Depression Scale	Baseline, 6 th week, and 12 th week	There was statistically significant improvement in pain outcome for the	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
	controlled double-blind study	pain			N = 20	(HADS), Short-form 36 (SF-36)		ESWT group when compared to control at both week 6 and week 12 (p < 0.05)	
(Elchami et al. 2011) ⁷⁶	Clinical trial	• 61 patients with lower back pain • 31 females and 30 males with ages ranging from 23-85	• Patients receiving either 3 sessions (n = 35) or 6 (n = 37) sessions of ESWT • ESWT (0.15-0.25 mJ/mm², 500-2000 pulses, 15-30 mm depth focus) was applied to the facets, paravertebral muscles and radiating triggered muscles	Focused	Comparison to baseline	Pain improvement	Baseline, and as patients approached 6 sessions of treatment	An average pain improvement of 60% was found in patients approaching 6 sessions of treatment	No significant events were reported

Table 5. Clinical Outcomes from Selected Extracorporeal Shockwave Therapy Studies for Non-Musculoskeletal Conditions

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
Chronic Pelvic Pain Syndrome/Chronic Prostatitis									
(Labetov et al. 2024) ⁷⁷	Systematic review and meta-analysis	Patients with chronic prostatitis/ chronic pelvic pain syndrome	Patients receiving ESWT	Not specified	Placebo ESWT or medication therapy	Primary outcomes were pain (VAS) and the NIH-CPSI questionnaire	Baseline, 1 month or 2 months, 3 months, and 6 months	ESWT group had more pronounced pain relief compared with control groups at the 6-month follow-up ($p < 0.01$)	No significant events were reported
(Skaudickas et al. 2023) ⁷⁸	Clinical trial follow-up	• 28 patients with prostatitis/ chronic pelvic pain syndrome • Mean age was 47.1 ± 13.7	Patients receiving low-energy ESWT once weekly (0.25 mJ/mm², 3 Hz) for 4 weeks	Focused	Comparison to baseline	Pain (VAS), National Institutes of Health Chronic Prostatitis Symptom Index (NIH-CPSI), and International Index of Erectile Function (IIEF)-5	Baseline, 4 weeks, 12 weeks, 24 weeks, and 48 weeks after treatment	ESWT treatment resulted in significant improvement in VAS score, with symptom regression being experienced as early as 4 weeks after treatment ($p < 0.001$) and lasting to 24 weeks ($p < 0.05$) and 48 weeks ($p < 0.001$)	No significant events were reported
(Kim et al. 2021) ⁷⁹	Prospective-Randomized, Double Blind, Placebo-Controlled Study	30 patients with chronic prostatitis/ chronic pelvic pain syndrome	Patients receiving multifocal low-intensity ESWT (500 shocks each region, 0.26 mJ/mm², 3 Hz) N = 15	Focused	Placebo ESWT N = 15	Pain (VAS), the National Institutes of Health Chronic Prostatitis Symptom Index (NIH-CPSI) total and subdomain scores, International Prostate Symptom Score (IPSS), and the International Index of Erectile Function-5 (IIEF-5)	Baseline, immediately after finishing treatment, and 4 weeks after the treatment	Compared to placebo, the ESWT group experienced statistically significant improvements in VAS immediately after treatment ($p < 0.001$) and after 1 month ($p = 0.002$)	No significant events were reported
(Trishch et al. 2021) ⁸⁰	Clinical trial	• 63 patients with non-inflammatory chronic pelvic pain syndrome • Aged 29 to 45 years • Patients had a disease duration of more than 3 years and a low efficacy of treatment against the background of standard therapy	Patients receiving ESWT (twice a week for a month, 3000 pulses, 10 Hz, 1.5-2 bar, 90-120 mJ) in addition to standard conservative therapy N = 33	Radial	Patients receiving standard conservative therapy consisting of antibiotics, nonsteroidal anti-inflammatory drugs, alpha-blockers, muscle relaxants for a month N = 30	Pain or discomfort, violations of urination, impact of the disease on everyday life, quality of life, and total score (NIG-CPSI)	Immediately after the end of treatment, 3 months, and 6 months after treatment	• Patients in the ESWT group experienced significant improvements in pain or discomfort after treatment ($p = 0.023$), after 3 months ($p = 0.018$), and after 6 months ($p = 0.018$) • Patients in the control group also experienced significant ($p < 0.05$) improvement in pain, but symptoms had a tendency of returning	No significant events were reported
(Birowo et al. 2020) ⁸¹	Systematic review and meta-analysis	3 studies on patients with chronic non-bacterial prostatitis	Patients receiving ESWT	Focused	Patients receiving sham ESWT treatment	Pain domain, urinary score, quality of life, and National Institutes of Health chronic prostatitis symptom index (NIH-CPSI) score	Baseline, and anywhere from 1 to 12 weeks	ESWT was found to be significantly associated with decreased pain domain ($p < 0.001$) after 12 weeks of treatment	No significant events were reported

Reference	Study Design	Patient Population	Treatment Group	Type of Shockwave Therapy (Radial or Focused)	Control Group	Outcomes Assessed	Patient Assessment Time Points	Analgesic Outcomes	Adverse Effects
							following the first ESWT treatment		
Ulcers									
(Taheri et al. 2021) ⁸²	Randomized controlled trial	• 44 patients with chronic venous ulcers with persistence for more than 6 weeks • Mean age of 56.1 ± 15.1 in the ESWT group and 57.3 ± 11.8 in the control group • Patients had an ulcer size of more than 1 cm^2 • 39 males and 5 females	Patients receiving ESWT (100 pulses/square centimeter of wound area, 3.5 mJ, 5 Hz once a week for 4 weeks along with compression bandaging N = 22	Radial	Patients receiving sham ESWT and compression bandaging N = 22	Pain intensity (VAS), patients' quality of life, wound size (cm^2), amount of drainage (no, low, moderate, high), and patient satisfaction	Baseline, 4 weeks, and 8 weeks	Patients in the ESWT group did not have significantly lower pain scores when compared to control ($p = 0.860$)	No significant events were reported
(Huang et al. 2020) ⁸³	Systematic review and meta-analysis of randomized controlled trials	• 8 randomized controlled trials on patients ($n = 339$) with diabetic foot ulcers were included • Diabetic foot ulcers were of neuropathic, neuroischemic or ischemic etiology, irrespective of type 1 or type 2 diabetes	Patients receiving ESWT and standard wound care	Mixed	Patients receiving standard wound care or standard wound care with hyperbaric oxygen therapy	Ulcer-related pain (VAS and pain self-assessment numeric box scale), reduction of wound surface area, and percentage of re-epithelialization	Baseline, and then anywhere from 5 to 24 weeks after treatment	• Patients in the ESWT group reported remarkable pain relief in one study and no significant improvement in another study • For these studies that reported pain scores, significance levels were ($p < 0.001$) and ($p > 0.05$)	Some patients reported transitory skin reddening, slight pain, and small hematomas

for activation.⁵¹⁻⁵⁴ The positive effects of NO produced via cNOS likely come from the fact that NO is regulated and produced in low concentrations to act as a fast chemical messenger for cell-to-cell communication in processes necessary for healthy organisms and the promotion of homeostasis.⁵¹⁻⁵⁵ The iNOS isoform, on the other hand, is expressed within macrophages, microglia, endothelial cells, neurons, and astrocytes and is associated with damage that occurs as NO accumulates in high concentration.^{51,56} This isoform acts independent of calcium activation and produces large amounts of NO, eliciting a cytotoxic effect on nearby tissues as a result of peroxynitrite formation from the reaction between NO and superoxide radicals, which ultimately leads to nociception.⁵⁷⁻⁶¹ Peroxynitrite's cytotoxicity arises from its nitration of protein tyrosine residues, oxidation of thiol groups, and activation of the poly ADP-ribose polymerase (PARP), which may cause cell death.⁵⁷ However, this cytotoxic effect in some instances may be beneficial because damaged cells and invading pathogens may be swiftly destroyed.⁶² Additionally, high levels of iNOS-produced NO may promote healing of intestinal mucosa via regulation of T cell proliferation and differentiation.⁵⁷

Another brief, yet important NO pain pathway to consider is the through the involvement of nuclear factor-kappa B (NF- κ B). NO is known to have a modulatory effect on the activity of NF- κ B, which is a prominent nuclear factor that controls the expression of numerous inflammatory genes.⁶² More specifically, NF- κ B activation leads to the production of proinflammatory cytokines such as interleukin-1 beta (IL-1 β), and tumor necrosis factor-alpha (TNF- α), which, in a positive-feedback loop, activate NF- κ B.⁶³ IL-1 β , produced by macrophages, monocytes, glial cells, and other cell types, has been shown to be involved in inflammatory pain hypersensitivity through its mediation of the induction of cyclooxygenase-2 (COX-2) in the central nervous system (CNS).^{49,64} Similarly, IL-1 β has been found to stimulate prostaglandin production, which sensitizes nociceptors and may contribute to persistent pain.⁶⁴

MAINTENANCE OF CHRONIC PAIN

Lastly, in the discussion of the underlying mechanisms that establish chronic inflammatory pain, mechanisms concerning the maintenance of this pain should be considered. To draw contrast, acute pain involves nociceptive signals being mediated by the action of glutamate on α -amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA) and kainite subtypes of ionotropic glutamate receptors of postsynaptic neurons to generate an excitatory postsynaptic potential.²³ If the noxious stimulus is persistent or intense, depolarization of postsynaptic neurons activates N-methyl-D-aspartate (NMDA) receptors, which leads to calcium cation influx and activates intracellular pathways that further promote calcium production through the same NMDA receptors.²³ GPCRs such as EP, NK1, and mGlu that are present on superficial dorsal horn nociceptor terminals are also able to control NMDA receptors, and thus contribute to central sensitization and the maintenance of chronic pain.^{65,66}

EXTRACORPOREAL SHOCKWAVE THERAPY AND MECHANISMS OF ACTION

EXTRACORPOREAL SHOCKWAVE THERAPY

ESWT is a non-invasive treatment that uses mechanical shockwaves to stimulate tissues, promote healing, and reduce pain.^{67,68} Starting in 1980, the use of ESWT was primarily for kidney and urinary stone lithotripsy until around 25 years ago, where ESWT was discovered to have immediate anti-inflammatory and antalgic effects at lower energy levels (0.03 to 0.011 mJ/mm²).^{62,68} The technology functions to produce an acoustic extracorporeal shockwave characterized by high positive pressures greater than 100 MPa that is generated in a small amount of time (10⁻⁹ seconds).^{68,69} This positive pressure wave is then followed by a low pressure phase with a tensile stress equal to 10 MPa.⁶⁸ The pulse duration of ESWT at low frequency is very short (around 5 μ s), which serves the technique well because it minimizes shockwave absorption and subsequent thermal effect.⁶⁸

There are two major types of ESWT: focused shockwave therapy (FSWT) and radial shockwave therapy (RSWT).⁷⁰ FSWT produces a maximal pressure field that is concentrated at a particular depth in specific tissues.⁷⁰ These shockwaves can be produced electromagnetically (EM), electrohydraulically (EH), or piezoelectrically (PE).⁷¹ Each of these techniques use water as a medium to facilitate shockwave propagation into tissues due to their acoustic similarities. The differences between each type of FSWT lie in the timing of their shockwave generation, namely in the fact that EH FSWT generates shockwaves immediately after the spark gap, whereas PE and EM FSWT incorporate a delay of a few nanoseconds.⁷⁰ RSWT, on the other hand, produces a diverging pressure field, with the maximal pressure field being produced at the source instead of within the tissues.⁷⁰ The mechanism of shockwave generation is not through water, but instead through the use of compressed air to accelerate a projectile through a tube into an applicator.⁷⁰ Fundamentally, a key difference between FSWT and RSWT is that the FSWT is more suitable for deeper tissue stimulation, whereas RSWT might be more effective superficially.⁷⁰

THERAPEUTIC EFFECTS AND MECHANISMS OF ACTION

ESWT is known to have multiple therapeutic effects in musculoskeletal, inflammatory, and injury-related conditions.^{72,73} The general mechanism for ESWT's therapeutic effect is believed to be mediated by mechanotransduction, which is the process by which physical forces are converted into biochemical signals.⁷⁴ Mechanotransduction in the context of ESWT occurs in four phases.⁷⁵ The first of these phases is the direct mechanical phase, which involves the propagation of the actual shockwave through the tissues.⁶⁸ The positive phase of the shockwaves causes tissue absorption and extracellular cavitations to occur, leading to ionization of molecules and increased membrane permeability.^{68,70} More specifically, cavitations refer to the gen-

eration of small air bubbles in the tissues during the negative phase of the wave, which, when ruptured at high speed, produce secondary shockwaves and an inflow of micro water jet streams that can reach velocities of up to 700 m/s.^{68,70} The water masses can then cause small hemorrhages in tissues, which at the cellular level produces free radicals, contributes to shear stress, and damages cell membranes.^{62,68} The second phase of mechanotransduction is the physical-chemical phase, which involves the interaction of radicals with biomolecules of the lysosomes and mitochondria, interfering with metabolic activities in the cell.⁶⁸ Additionally, this phase is characterized by the release of adenosine triphosphate (ATP), which activates various cell pathways.⁷⁰ The third phase is the chemical phase, in which shockwaves alter the function of ion channels in cell membranes and mobilize calcium.⁷⁰ The fourth and final phase is the biological phase, where ESWT initiates anti-inflammatory effects, angiogenesis, and overall regeneration.^{68,70} Indeed, cells are known to dynamically adapt to force by modifying their behavior through the release of growth factors and cytokines such as insulin-like growth factor 1 (IGF-1) interleukin-6 (IL-6), and transforming growth factor- β 1 (TGF- β 1).⁷⁴ However, the specific physiological mechanism by which ESWT-derived analgesia is achieved is not fully understood.⁷² Therefore, in the sections below we will highlight some of the proposed mechanisms found in the literature, which may be interrelated.

NO THERAPEUTIC MECHANISM

The first mechanism that we will discuss is that which involves NO. At low, non-cytotoxic physiological concentrations (<50 nM), NO is known to be a powerful suppressor of the activation of NF- κ B.⁷⁶ During periods of inflammation, eNOS-produced NO may drop below levels that are considered normal within “NO homeostasis”.⁶² In a study where human umbilical vein endothelial cells (HUVEC) were treated with lipopolysaccharides (LPS) and cytokines to mimic inflammatory conditions, a rapid drop in both eNOS activity and NO concentration was observed.⁶² Since NO suppresses NF- κ B, instances in which NO concentration drops far below the homeostatic level may lead to the local activation of NF- κ B, which would promote the expression of numerous inflammatory mediators and ultimately lead to inflammatory pain.^{62,63} Shear stress produced by ESWT combats this by enhancing the production of eNOS-derived NO.⁶² An experiment in 2002 found that ESWT, under mimicked physiopathological conditions, resulted in the production of physiologically relevant amounts of NO (108 ± 16 nM) after 1500 shots at an energy level of 0.89 mJ/mm².⁷⁷ Similarly, the previously discussed HUVEC study found that ESWT was able to increase eNOS activity and NO production with 1000 shots at an energy level of 0.03 mJ/mm². ESWT was also found to efficiently downregulate NF- κ B activation.⁶² Another study on rat glioma C6 cells (which express both cNOS and iNOS) yielded similar results in that ESWT downregulated not only NF- κ B, but also iNOS expression and other inflammatory genes dependent on NF- κ B.⁷⁸

The analgesic therapeutic effect of ESWT that proceeds through NO production is postulated to have two primary mechanisms that mediate these effects. The first is through the NO-sensitive soluble guanylyl cyclase (sGC), which converts guanosine triphosphate (GTP) into guanosine 3',5'-cyclic monophosphate (cGMP).⁴⁸ Administration of cGMP and factors that promote cGMP signaling have been found in one study to promote analgesia.⁷⁹ As a part of sGC signaling, substances that release NO non-enzymatically, such as sodium nitroprusside have been shown to inhibit PGE2-induced inflammatory hyperalgesia – an effect that was improved by administration of cGMP and blocked by sGC inhibitors, thus giving credence to the role of NO-mediated sGC signaling on peripheral analgesia.⁴⁸ The other proposed mechanism involves NO acting on primary sensory neurons (PSN), which reduces glutamate release via a mechanism reliant on S-nitrosylation of voltage-activated calcium channels.⁴⁸ A few studies suggest the role of this mechanism in mediating PSN sensitivity and thus peripheral analgesic effects.^{80,81}

NEURONAL THERAPEUTIC MECHANISMS

With regard to mechanisms of analgesia that directly involve neurons, there have been three notable hypotheses that have been put forward. The first proposes that ESWT degenerates nerve fibers composed of small immunoreactive neurons, which decreases the concentration of pro-inflammatory mediators.⁷⁰ The second hypothesis is that ESWT may provide analgesia by hyperstimulation, meaning that shockwaves cause the release of endorphins and other molecules via the activation of the descending inhibitory nociceptive tracts and systems of the spinal cord.^{70,82} Depending on the state of the descending inhibitory system, it is believed that the amount of pain produced by a primary nociceptive stimulus will be reduced after the presentation of a secondary nociceptive stimulus as a result of ESWT's activation of endogenous analgesia, which is thought to be our body's natural pain inhibition system.^{70,83} However, a third mechanism, based on studies performed in animals, suggests that ESWT influences pain communication to the brainstem via action of substance P, neurovascular sprouting, and on calcitonin gene-related peptide (CGRP) expression in the dorsal root ganglion.^{70,85-89}

MACROPHAGE PHENOTYPE THERAPEUTIC MECHANISM

Another mechanism from which ESWT may derive its analgesic effects is through alteration of macrophage expression. A study in 2014 observed that low-energy ESWT stimulates a polarity shift in macrophage phenotype from M1 to M2.^{70,90} The M1 phenotype has a pro-inflammatory role and is activated by pathogenic substances.⁹¹ Its responses are associated with the production of interleukin-8 (IL-8), interleukin-12 (IL-12), and chemokine ligand (CCL), with the expression of cluster of differentiation (CD) 80 and 86 that attract killer neutrophil cells, and with T helper type 1 (Th1) responses that are involved in inflammation.^{92,93} In contrast, the M2 macrophage phenotype is generated by the T helper type 2 (Th2) response and demonstrates an anti-

inflammatory function characterized by the production of interleukins 4 (IL-4), 5 (IL-5), 9 (IL-9), and 13 (IL-13).⁷⁰ M2 macrophages have also been shown to stimulate angiogenesis cell repair and proliferation through collagen and polyamine synthesis, and their release of cytokines and growth factors, which contributes to the overall Th2 response in its regenerative processes after injury.⁷⁰ Given that inflammation has previously been discussed as a cause for pain and central sensitization, it is reasonable to assume that ESWT's reduction of this inflammation via alteration of macrophage phenotype may provide analgesic benefits.

MAPK THERAPEUTIC MECHANISM

The final therapeutic mechanism we will discuss is a pathway that proceeds through mitogen-activated protein kinases (MAPKs). It is already known that ESWT produces mechanical stimulation through pressure changes that elicit a biological response.⁹⁴ One pathway through which ESWT may achieve its biological effects could be through the activation of the following MAPKs: extracellular signal-regulated kinase 1/2 (Erk1/2) and p38.⁹⁴ In general, MAPK signaling pathways are important in cell proliferation, apoptosis, differentiation, development, and inflammation.⁹⁴⁻⁹⁸ Erk1/2 specifically can activate hypoxia-inducible factor 1 α and angiogenesis through vascular endothelial growth factor A (VEGFA) expression.^{94,99} MAPK activation in particular cells such as immune cells, osteoblasts, and mesenchymal stem cells can induce differentiation and T cell proliferation, which may help alleviate various pathologies in particular musculoskeletal disorders.⁹⁴ For example, MAPK activation may contribute to the differentiation of mesenchymal stem cells (MSCs) into new tenocytes and osteoblasts and thus promote healing in various tendinopathies and osseous disorders, thereby reducing pain.¹⁰⁰⁻¹⁰⁵

DISCUSSION OF CLINICAL EVIDENCE FOR EXTRACORPOREAL SHOCKWAVE THERAPY FOR PAIN MANAGEMENT

PATIENT POPULATION

Within the studies included in this review, the patient population consisted of patients suffering from various musculoskeletal and non-musculoskeletal conditions that cause chronic inflammatory pain. Specific conditions reported include tendinopathies such as those of the shoulder, knee, elbow, and achilles, as well as greater trochanteric pain, de quervain tenosynovitis, conditions causing myofascial pain, plantar fasciitis (PF), fibromyalgia, osteoarthritis (OA), fractures, osteonecrosis (ON), bone edema, coccydynia, conditions causing low back pain, chronic pelvic pain syndrome/chronic prostatitis, ulcers, and carpal tunnel syndrome (CTS) (Tables 1-5). Of the studies in the Tables 1-5 that reported mean age, the average age throughout all chronic pain conditions was 45.64 years, which is consistent with the age range that is most commonly associated

with chronic pain (Tables 1-5).⁶ Other metrics reported within the patient section of the studies included data on gender distribution, such as in (Louwerens et al. 2020), (Kamonseki et al. 2024), (Pabón-Carrasco et al. 2024), (Aktürk et al. 2018), and (Guler et al. 2020), did not report any significance of gender on analgesic outcomes (Tables 1-5). Other studies specified the duration that patients had chronic symptoms for, including ≤ 36 months for carpal tunnel syndrome (VONGVACHVASIN et al. 2023),¹⁰⁶ ≥ 3 months for lower back pain (Back et al. 2024)¹⁰⁷ (Yue et al. 2021),¹⁰⁸ > 3 years for chronic pelvic pain syndrome (Trishch et al. 2021),¹⁰⁹ and > 6 weeks for chronic venous ulcers (Taheri et al. 2021).¹¹⁰ Regarding prior treatments, there are 2 studies that report on previous interventions, such as neck surgery (Kamel et al. 2020), and failed conservative management (Abdelkader et al. 2021). Overall, the patient population included in this review reflects the variety of chronic conditions and etiologies through which chronic pain is manifested.

TYPE OF EXTRACORPOREAL SHOCKWAVE THERAPY USED

Many studies in Tables 1-5 reported on the type of ESWT that was used. As described in earlier sections, ESWT used in clinical practice are either radial or focused in nature. Radial ESWT produces a diverging pressure field, with the maximal pressure field being produced at the source instead of within the tissues, while focused ESWT produces a maximal pressure field that is concentrated at a particular depth in specific tissues.⁷⁰ Since these types of ESWT differ in the location of the maximal pressure, various studies sought to examine the difference in analgesic effect between them. For example, (Li et al. 2021), (Hyun et al. 2021), and (Kaplan et al. 2023) found FSWT to be more effective than RSWT in reducing pain (Table 1). On the contrary, (Brindisno et al. 2024) found FSWT and RSWT to be equally effective at reducing pain, while (Xie et al. 2022) found RSWT to be effective and FSWT to not be effective at reducing pain (Table 1). Although results in this review are mixed, the literature has alludes to the idea that efficacy of either type may be related to the condition being treated.¹¹¹ To be specific, a study on non-calcific rotator cuff tendinopathies and another study on knee arthritis found FSWT to be significantly more effective than RSWT at long term follow-up (> 24 weeks), while a different study found no significant difference in efficacy between FSWT and RSWT in the treatment of plantar fasciitis.¹¹¹ 2 studies included in this review, which were (Abo Al-Khair et al. 2021) and (El-Mallah et al. 2020), combined FSWT and RSWT in order to observe their aggregate effect on treating chronic pain conditions and reported statistically significant improvements (Table 1). 3 studies also reported which type of FSWT that they used, namely (Louwerens et al. 2020) using piezoelectric, (Krogh et al. 2021) using electrohydraulic, and (Gatz et al. 2021) comparing point-focused and line-focused ESWT, showing moderately positive results with limitations (Table 1). Concerning factors such as shockwave frequency, energy level, and treatment session frequency, not many studies offered comparisons,

except for (Brindisno et al. 2024), (Zhang et al. 2021), and (Sun et al. 2022), which compared different ESWT energy levels (Tables 1 and 4). (Brindisno et al. 2024) found high energy ESWT to produce more favorable pain outcomes in calcific rotator cuff tendinopathy than low energy ESWT, which contrasts the results of (Sun et al. 2022), which examined the effects of low intensity ESWT (4000 pulses at 0.03 mJ/mm^2) versus medium intensity ESWT (4000 pulses at 0.09 mJ/mm^2) and found that low intensity ESWT was better at reducing VAS pain score at 2 weeks, 4 weeks, and 6 weeks after the beginning of treatment (Tables 1 and 4). (Zhang et al. 2021) found that higher higher intensity ESWT (0.24 mJ/mm^2) provided significantly better pain outcomes than lower intensity ESWT (0.12 mJ/mm^2) ($p < 0.001$).¹¹² Of studies that reported treatment session frequency, the majority had either multiple sessions per week, or sessions at 1-week intervals (Tables 1-5). Of the studies that reported shockwave device frequency, the range was from 2 Hz to 16 Hz (Tables 1-5).

ANALGESIC OUTCOMES, DURATION, AND ADVERSE EFFECTS

The analgesic outcomes for the studies included in Tables 1-5 were generally positive and statistically significant. The majority of studies reported analgesic outcome on a standardized scale, such as the Visual Analogue Scale (VAS), Numeric Rating Scale (NRS), Numeric Pain Rating Scale (NPRS), and or metrics that evaluated the severity of the condition being treated such as the Victorian Institute of Sport Assessment-Achilles (VISA-A), the Boston Carpal Tunnel Questionnaire (BQ), and others (Tables 1-5). Given that the analgesic effects and duration of relief varied by condition, the following sections will evaluate the efficacy and safety of ESWT in various pathologies.

SHOULDER TENDINOPATHIES

For shoulder tendinopathies, including those with or without calcification that can affect structures like the rotator cuff and or the supraspinatus in one or both shoulders, ESWT had a significant desirable effect on pain – especially in the short term (Table 1). A very recent systematic review and meta-analyses on 16 randomized controlled trials including 1093 patients with rotator cuff tendinopathy found ESWT (both focal and radial) to have a very statistically significant effect on pain reported by the VAS ($p < 0.00001$).¹¹³ Similarly, another systematic review and meta-analysis on 21 randomized controlled trials that focused on calcific rotator tendinopathies specifically also found ESWT to have a very significant effect on pain when compared to control at 24 weeks ($p < 0.00001$).¹¹⁴ However, while these two meta-analyses and other clinical trials described in Table 1 support the efficacy of ESWT, a recent systematic review and meta-analysis on noncalcific rotator cuff tendinopathy that included 9 studies and 543 patients found that although ESWT had significantly superior effects to control at short-term follow-up ($p = 0.04$), these effects waned at the intermediate and long-term follow-up ($p > 0.05$).¹¹⁵ Indeed, clinical trials such as (Louwerens et al. 2020) and (Efe et

al. 2014) found ESWT to not have significant effect on both noncalcific and calcific shoulder tendinopathies starting at 3 months follow-up.^{116,117} Therefore, with regard to duration, the shortest duration of effect reported for shoulder tendinopathies in Table 1 was 3 months, while the longest duration reported was 48 weeks (Table 1). ESWT for shoulder tendinopathies was overall safe, with minimal adverse events reported. In one study, 8 patients reported moderate pain, 1 patient reported syncope, 1 patient reported migraine, and 2 patients reported skin redness.¹¹⁸ In another study, one ESWT patient developed a frozen shoulder, but their symptoms resolved during the follow-up period.¹¹⁶

LATERAL EPICONDYLITIS

Lateral epicondylitis, colloquially referred to as “tennis elbow”, is a painful condition that affects the upper extremities and is the most common diagnosis made in patients with elbow lesions, with a prevalence rate of 1% to 3% in the population.^{119,120} All studies included in Table 1 on lateral epicondylitis indicated the positive outcome of ESWT on pain. For example, a systematic review and network meta-analysis on 40 randomized controlled trials found that ESWT was significantly efficacious in VAS improvement when compared to placebo (SMD, -0.57 [95% CI, -0.89 to -0.25]).¹²¹ Another meta-analysis on 27 clinical trials including 1871 patients reported that ESWT reduced pain intensity at mid-term follow-up when compared to placebo sham ESWT, although the evidence quality was rated as low to moderate ($p < 0.001$).¹²² This positive trend in pain outcomes after ESWT has continued up through very recent randomized controlled clinical trials that likewise cite significant declines in pain scores such as VAS and the patient-rated tennis elbow evaluation (PRTEE) when compared to placebo control ($p < 0.001$).^{123,124} The analgesic effect of ESWT, as reported by the studies in Table 1, seems to be stable throughout short-term and medium-term follow-up periods, with no studies reporting any loss of significant effect and the longest duration being at least 13 weeks (Table 1). The intervention also appears to be relatively safe, with only 1 study reporting an adverse effect, which was transient pain in the treated elbow (however the patient did not stop the therapy).¹²⁵

ACHILLES TENDINOPATHY

Achilles tendinopathy is a condition characterized by tendon pain, swelling and impaired performance and is most prevalent among individuals who participate in orienteering, running, tennis, badminton, soccer, and volleyball.¹²⁶ The studies included in Table 1 on the efficacy and outcomes of ESWT for achilles tendinopathy are mixed. One recent systematic review and meta-analysis on 63 studies concluded with low to moderate evidence certainty that ESWT may have an effect on achilles tendinopathy in the short term, while another meta-analysis on 6 studies concluded that there were no significant differences found between ESWT and control groups for any pain metric.^{127, 128} Other systematic reviews in Table 1 reported either mixed results or evidence of low to moderate quality in-

dicating that ESWT may have a positive effect on achilles tendinopathy symptoms (Table 1). The clinical trials included in this section of Table 1 likewise find both significant differences and insignificant differences in pain and function outcomes. One potential reason behind the lack of concurrence in the data could be that chronic achilles tendinopathy is not considered to be an inflammatory condition, which may hinder the mechanism of action through which ESWT provides analgesia.¹²⁶ Of the studies that indicated a positive effect of ESWT on achilles tendinopathy, the duration of effect ranged from 6 weeks to 16 months (Table 1). ESWT for this condition also appears to be safe, as there were no reported significant adverse events in any of the studies.

PATELLAR TENDINOPATHY

Patellar tendinopathy is a common knee pathology that often presents with anterior knee pain.¹²⁹ The condition is most common in athletes that participate in jumping sports such as volleyball and basketball.¹²⁹ The studies reported in Table 1 on ESWT for patellar tendinopathy indicate that the treatment may have a positive effect on pain outcomes, at least in the short-term (Table 1). A systematic review and meta-analysis on 63 studies including patients suffering from patellar tendinopathy concluded with low to moderate certainty of evidence that ESWT can reduce pain and improve function in the short-term, which was defined as ≤ 3 months.¹²⁷ This result was supported by a randomized double-blind placebo-controlled trial that found ESWT to be significantly more effective than placebo at reducing pain while walking ($p = 0.011$).¹³⁰ However, this trial found no statistical difference in pain at rest or when the tendon was squeezed ($p = 0.221$).¹³⁰ Although there are few studies to base conclusions from, the treatment seems to be relatively safe, with efficacy lasting for at least 12 weeks.

GREATER TROCHANTERIC PAIN

Greater trochanteric pain syndrome (GTPS), which can be caused by greater trochanteric bursitis and gluteus minimus and medius tears, is a condition that is characterized by chronic pain along the lateral aspect of the hip.^{131,132} This condition, which is believed to affect around 1.8 patients per 1000 per year, usually has a physical examination finding of point tenderness in the posterolateral region of the greater trochanter.¹³² Evidence of the use of ESWT for the treatment of greater trochanteric pain syndrome is extremely limited, but a very recent systematic review and meta-analysis on 12 studies (1121 patients) revealed no statistically significant effect on pain improvement after ESWT when compared to control (Table 1). However, this evidence quality was reported to be moderate, indicating that perhaps more in-depth study may yield more conclusive results. Although statistically ineffective, the intervention can likely be considered relatively safe because there were no adverse events reported in the study included within Table 1.

DE QUERVAIN TENOSYNOVITIS

De Quervain Tenosynovitis is a common wrist pathology that causes pain due to gliding resistance of the abductor pollicis longus and the extensor pollicis brevis tendons in the fibro-osseous canal.¹³³ Clinical evidence on the use of ESWT for de Quervain Tenosynovitis is very limited, as the literature search yielded only one clinical trial with 26 patients (Table 1). The study found that VAS pain score decreased significantly in the intervention group, which received RSWT, when compared to the placebo control group ($p < 0.05$).¹³⁴ Patient follow-ups were held at 6 weeks and 2 months after treatment, which indicates an effect duration of at least 2 months since no period at which the effects were statistically insignificant was reported. However, further experimentation will be needed to determine true clinical efficacy. The intervention was overall safe, as no significant adverse events were reported.

CARPAL TUNNEL SYNDROME

CTS is a common condition that occurs when the median nerve is compressed as it travels through the wrist, and causes pain, tingling, and numbness in the upper extremities of affected individuals.¹³⁵ Within the CTS section of Table 1, most studies concluded that ESWT had a significant effect on reducing pain in the short-term. For example, a systematic review and meta-analysis on 7 randomized controlled trials including 376 patients found that ESWT treatment groups had significantly lower VAS pain scores at the 4 week follow-up assessment, after which clinical effects declined into insignificance at 8 weeks and 12 weeks.¹³⁶ This finding is corroborated by some recent clinical trials included in the CTS section of Table 1 that found ESWT to be significantly effective in reducing pain after 1 month ($p < 0.001$) and 6 weeks ($p < 0.05$) respectively.^{106,137} However, there were also clinical trials that concluded longer effect durations, including periods up to 8, 12, 14, and 24 weeks.¹³⁸⁻¹⁴² Another systematic review and meta-analysis on 10 trials including 433 patients found RSWT to be significantly effective at reducing pain ($p = 0.03$) at an undetermined follow-up period.¹⁴³ Overall, the data seems to conclude that ESWT is effective for pain with a moderate duration of effects, however further investigation is still warranted. Adverse events were minimal, with some patients reporting transient wrist pain, and skin redness.

GENERAL MYOFASCIAL PAIN

Myofascial pain syndrome (MPS) is a painful musculoskeletal pathology that arises from localized tense regions of fascia and skeletal muscle, which are referred to as “trigger points”. Prevalence rates of MPS vary, but over a lifetime it is believed to be 85%.¹⁴⁴ The studies in the MPS section of Table 2 overwhelmingly conclude that ESWT has a significantly positive effect on pain from MPS. A systematic review and meta-analysis on 27 trials including 1377 patients reported that ESWT was significantly effective in relieving pain when compared to control.¹⁴⁵ Similarly, another meta-analysis on 11 randomized controlled trials found that

ESWT had a large effect on improving pain intensity and pressure pain threshold ($p < 0.05$). Several clinical trials likewise confirmed the efficacy of ESWT, citing significant pain improvements when compared with control ($p < 0.05$).¹⁴⁶⁻¹⁵¹ However, there were a few studies that found ESWT to have minimal effects on pain improvement when compared to conventional treatment, or with significant effects waning after 30 days.^{146,152} The duration of clinical effect was generally greater than 3 weeks, with the longest reported follow-up duration being 4 months (Table 2). The intervention was largely safe, although some patients reported pain and redness of the skin, but none dropped out of the studies.

PLANTAR FASCIITIS

PF is a common painful musculoskeletal injury of the foot that is believed to account for over 1 million physician visits annually in the U.S and affects around 17.4% of the running population.¹⁵³ Studies reported in the PF section of Table 2 largely supported ESWT and its effect on pain in the short-term, medium-term, and long-term. For example, a systematic review and meta-analysis on 63 studies concluded with high certainty of evidence that ESWT has a large effect on reducing pain in PF in the short-term (≤ 3 months), mid-term (> 3 months - ≤ 6 months), and long term (≥ 12 months).¹²⁷ Other meta-analyses and clinical trials reported in Table 2 supported the significant efficacy of ESWT after 4 weeks and 12 weeks ($p < 0.05$).¹⁵⁴⁻¹⁵⁶ However, one of the meta-analyses ($n = 867$ patients) in the PF section of Table 2 found ESWT to have no significant effect on VAS scores when compared to baseline values ($p = 0.06$) in follow-up durations from 1 to 6 months.¹⁵⁷ The intervention appeared to be safe, as there were no reported significant adverse events.

FIBROMYALGIA

Fibromyalgia is a condition characterized by chronic widespread pain and may cause sleep problems, cognitive difficulties, and physical exhaustion.¹⁵⁸ The prevalence of fibromyalgia symptoms is estimated to between 2% and 4% in the general population, and diagnosis typically involves history of a cluster of symptoms and the exclusion of a somatic disease that explains the symptoms via medical examination.¹⁵⁸ Previous reviews on ESWT for fibromyalgia report mixed conclusions. One review from 2015 found that RSWT may be a safe and effective early adjunctive therapy, whereas another scoping review from 2022 that responded to the previous review concluded that there was no evidence for ESWT in improving fibromyalgia symptoms.^{159, 160} However, since the publication of those reviews, there have been more studies evaluating ESWT's efficacy, including a randomized controlled trial within the fibromyalgia section of Table 2 that found clinically significant changes and improved pain scores within the ESWT group – although there was no statistically significant difference between the ESWT and the control group ($p = 0.61$).¹⁶¹ There were no reported adverse events during or after the intervention,

but more clinical trials are needed to determine ESWT's true efficacy, duration, and safety.

KNEE OSTEOARTHRITIS

Knee osteoarthritis (KOA) is a painful progressive condition that results from failed repair of joint damage from stresses initiated by joint or periarticular tissue abnormalities.^{162, 163} The disease has been ranked as the 10th largest contributor to years lived with disabilities globally, with a prevalence that has doubled over recent years.¹⁶³ All studies in the KOA section of Table 3 indicated the ESWT had a positive effect on pain outcomes. A recent systematic review and meta-analysis on 12 studies including 734 patients found that when compared to placebo, ESWT was significantly better for pain reduction in the short-term, medium-term, and long-term for pain ($p < 0.01$).¹⁶⁴ Included clinical trials concluded similar results, finding significant decreases in pain scores 10 days, one week after the end of treatment, and 4 weeks after treatment (Table 3). However, one systematic review on 24 studies with 888 patients concluded that while ESWT was effective for KOA in general, it was not effective for patients with severe KOA.¹⁶⁵ Adverse events were minimal, with some patients reporting minor skin reddening, pain, swelling, and a burning sensation.

FRACTURES AND NON-UNION

Bone fractures are a very common osseous injury that may result in non-union, which occurs when a fractured bone fails to heal and is unable to unite without intervention.¹⁶⁶ Non-union, as a complex condition, then causes chronic pain and functional disability.¹⁶⁶ The literature search yielded one result on ESWT for bone fractures and non-union (Table 3). This study was a systematic review, meta-analysis, and meta-regression on 8 studies that found ESWT to be significantly effective on reducing pain at 3 months ($p = 0.01$), 6 months ($p = 0.004$), and 12 months ($p = 0.04$).¹⁶⁷ The duration of effect with ESWT was anywhere between 12 and 24 months, since the meta-analysis reported that significant clinical effects waned at the 24 month follow-up ($p = 0.16$).¹⁶⁷ Since only one study on bone fractures and non-union was available for inclusion in Table 3, further investigation is warranted. The intervention appeared to be relatively safe, as no significant adverse events were reported.

OSTEONECROSIS OF FEMORAL HEAD

Osteonecrosis (ON) of femoral head is a condition that represents the culmination of a series of derangements that cause a decrease in blood flow to femoral head, which leads to cell death, fractures, and collapse of articular surfaces.¹⁶⁸ The disease is most prominent in young, active people between the ages of 20 and 40, with 20000 to 30000 new patients diagnosed annually.¹⁶⁸ The clinical evidence on ESWT for ON of femoral head reported in Table 3 supports the treatment's efficacy. A systematic review and meta-analysis of 8 studies concluded that when compared

to control, ESWT had favorable results on pain from conditions including femoral head necrosis at 3 months ($p = 0.01$), 6 months ($p = 0.004$), and 12 months ($p = 0.04$), finally losing statistical significance at 24 months ($p = 0.16$) (Garcia et al. 2024). Similarly, another earlier systematic review on 13 articles found that high energy ESWT were more effective in the earlier stages of the disease, compared to its later stages (Abbas et al. 2023). The duration of effect was, at its maximum, anywhere between 12 to 24 months (Table 3). However, since the literature search only yielded 2 studies on ESWT for ON of femoral head, further investigation is warranted. There were no significant adverse events reported.

BONE EDEMA

Bone marrow edema refers to a group of transient conditions such as osteoporosis of the hip, reflex sympathetic dystrophy, and regional migratory osteoporosis (RMO) that may cause pain.¹⁶⁹ Table 3 reports a single study on ESWT for bone marrow edema, which was a systematic review and meta-analysis, and meta-regression on 8 studies, and found that ESWT had a significant effect on reducing pain at 3 months, 6 months, and 12 months, finally losing efficacy at 24 months ($p = .167$). Therefore, according to our literature search, the duration of effect with ESWT was anywhere between 12 and 24 months. The lack of evidence for ESWT's utility in this condition calls for further investigation, but the treatment appears to be safe since no significant adverse events were reported.

COCCYDYNIA

Coccydynia is a painful disorder characterized by coccygeal pain that gets worse with pressure.¹⁷⁰ Individuals of all ages and either gender are able to be affected by the disease, however the average age of onset has been estimated as 40 years, with a 5 times greater prevalence in woman than in men.¹⁷¹ Clinical evidence of ESWT for treatment of coccydynia is limited, so the literature search yielded just one result reported in Table 3. This study was a randomized clinical trial involving 17 patients treated with RSWT and found that VAS scores decreased significantly at 1 week, 1 month, 2 months, and 6 months after treatment ($p < 0.001$).¹⁷² Since no other studies were reported, the duration of clinical effect is estimated as 6 months, and the intervention is assumed to be relatively safe since no significant adverse events were reported (Table 3). However, further high-quality investigation is needed to confirm these results.

LOW BACK PAIN

Low back pain is a prevalent condition that affects millions globally, and is expected to grow in its burden and prevalence over the next several decades due to population expansion and increased life expectancy.¹⁷ The clinical evidence on ESWT for the treatment of low back pain largely supports its efficacy (Table 4). For example, a systematic review and meta-analysis on 12 randomized controlled trials

including 632 patients found ESWT to cause significantly more pain relief than control at 4 weeks ($p < 0.001$) and 12 weeks ($p < 0.001$).¹¹¹ Another systematic review and meta-analysis on 22 studies including 1749 patients confirmed these results in that this study found the ESWT group to have very significantly lower VAS pain scores than control at 3 months ($p < 0.00001$).¹⁷³ Various clinical trials reported in the low back pain section of Table 4 have also indicated significant positive effects on pain reduction.^{107, 174-176} Regarding duration of effect, multiple studies reported successful follow-ups at a maximum of 3 months (Table 4). However, one systematic review and meta-analysis reported no statistically significant difference in pain improvement between the ESWT group and control at 3 months follow-up ($p > 0.05$).¹⁷⁷ The intervention had few significant adverse events, with some studies reporting pain during treatment, and local swelling on the day of treatment (Table 4).

CHRONIC PELVIC PAIN SYNDROME/CHRONIC PROSTATITIS

Chronic pelvic pain syndrome (CPPS) has been defined as pelvic area pain that lasts for over 6 months and is severe enough to limit function.¹⁷⁸ The prevalence of the condition is 3% to 10% and is more common among women than men.¹⁷⁸ Chronic prostatitis (CP), which is often associated with CPPS, refers to a group of symptoms that can cause pain and reduction in quality of life, with a prevalence of around 4.5-9% among the male population.¹⁷⁹ The studies reported in Table 5 support ESWT as an effective treatment for pain due to CPPS/CP. For example, a systematic review and meta-analysis found that the ESWT intervention group had more pronounced pain relief compared with control groups at 6-month follow-up ($p < 0.01$).¹⁸⁰ Another systematic review and meta-analysis on 3 studies likewise found ESWT to be significantly associated with decreased pain after 12 weeks of treatment ($p < 0.001$).¹⁸¹ Of the clinical trials and meta-analyses reported in the CPPS/CP section of Table 5, the longest duration of effect reported was 48 weeks after treatment ($p < 0.001$), though many studies reported follow-up durations greater than 3 months with significant effects persisting (Table 5). No significant adverse events were reported in any of the included studies.

ULCERS

Ulcers are a condition in which an open sore develops as a result of loss of epidermis, dermis, or mucosal membrane tissue.^{182,183} These wounds can develop in many places and can have multiple causes, such as vascular diseases, hematologic disorders, neoplasms, connective tissue diseases, drugs, infections, neurologic disorders, physical etiologies, and idiopathic origins.¹⁸³ The literature search yielded two studies on ESWT for treatment of ulcers, including a randomized controlled trial and systematic review with meta-analysis which overall reported mixed results (Table 5). The systematic review and meta-analysis was on 8 randomized controlled trials including 339 patients with diabetic foot ulcers and found that in one study, the ESWT group had re-

markable pain relief ($p < 0.001$), but insignificant improvement in another study ($p > 0.05$).¹⁸⁴ The clinical trial included 44 patients with chronic venous ulcers and found that patients in the ESWT group did not have significantly lower pain scores when compared to control ($p = 0.860$).¹¹⁰ Since only two studies on ESWT for the treatment of ulcer pain were included in this review, further investigation is warranted in order to determine efficacy and duration of effect. The only adverse events reported included some patients experiencing transitory skin reddening, slight pain, and small hematomas.

CONCLUSION

ESWT appears to be a relatively safe, promising treatment for various chronic pain conditions, especially those that

are inflammatory in nature. Many of the mechanisms through which ESWT carries out its therapeutic effect are unknown or poorly understood, but this narrative review should serve as grounds for further experimentation, both in the mechanism of ESWT and in the conditions it can be used to treat. The main limitation of this study is its lack of a quantitative analysis of homogenized studies. However, the literature search was systematic in how it identified recent studies to be discussed in this review. Overall, the field of shockwave therapy is one that will continue to grow, and it will be interesting to follow its developments in the coming years.

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