ESWT/ESWL Team of

RICHARD WOLF

spirit of excellence

PiezoWave² VET

Powered by ELvation® USA

PiezoWave² VET Equine

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Without expertise from ELvation USA, ELvation GmbH and all our equine PiezoWave users creation of this booklet would not have been possible.

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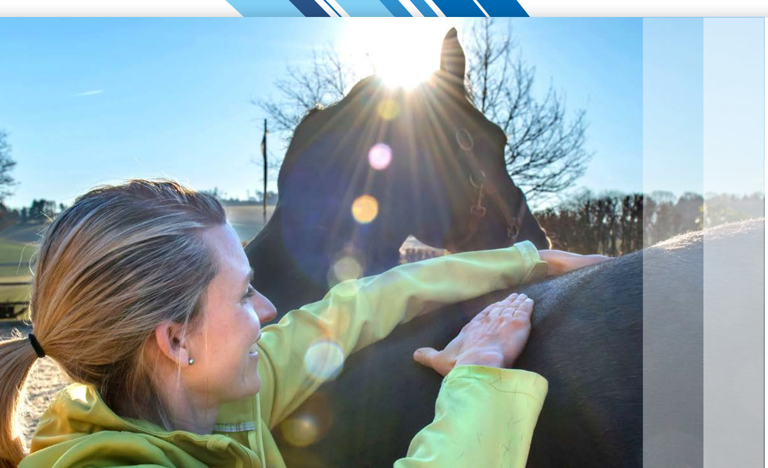
Section 1 - The Technology of shockwave therapy

History of extracorporeal shockwave therapy (ESWT)

ESWT developed from extracorporeal shockwave lithotripsy (ESWL), a technology that has been available for over 30 years. ESWL is a procedure in human medicine which uses acoustic shockwaves to break up kidney stones. Extracorporeal shockwave therapy (ESWT) was derived from ESWL and was initially used to treat human pseudarthrosis (non-unions). The first successful treatment of a human non-union by ESWT was reported in 1988 in Germany. Within two years, multiple clinical studies reported a success rate of 60-90% for healing of pseudarthrosis. Next, ESWT was shown to be successful for treatment of tendinitis calcarea, epicondylitis, and heel spur pain [1]. In human medicine, ESWT became a successful and viable non-surgical treatment for acute and chronic pain of the musculoskeletal system [2].
As the technology evolved, mobile units and therapy sources were developed and shockwave has become a useful solution for thousands of patients [3]. The benefits and impact of shockwave in human medicine have been impressively demonstrated in numerous studies [3,4]. ESWT was first FDA approved for the treatment of plantar fasciitis in 2000.

ESWT use in Equine medicine is well established and is commonly used for the treatment of bone and soft tissue conditions including but not limited to tendinitis, stress fractures/non-unions, back pain, and navicular syndrome[5].

For the purpose of clarity, the term shockwave will be used throughout this document meaning the equivalent to extracorporeal shockwave therapy, ESWT.



Basic principles of extracorporeal shockwave therapy

Shockwave therapy is a non-invasive procedure used to treat acute and chronic pain of the musculoskeletal system[3]. The source from which the shockwaves are generated is located outside the body (extracorporeal) and the shockwaves are delivered to areas deep inside the body. The focused shockwaves used in ESWT procedures reach their peak pressure precisely in the target tissue.

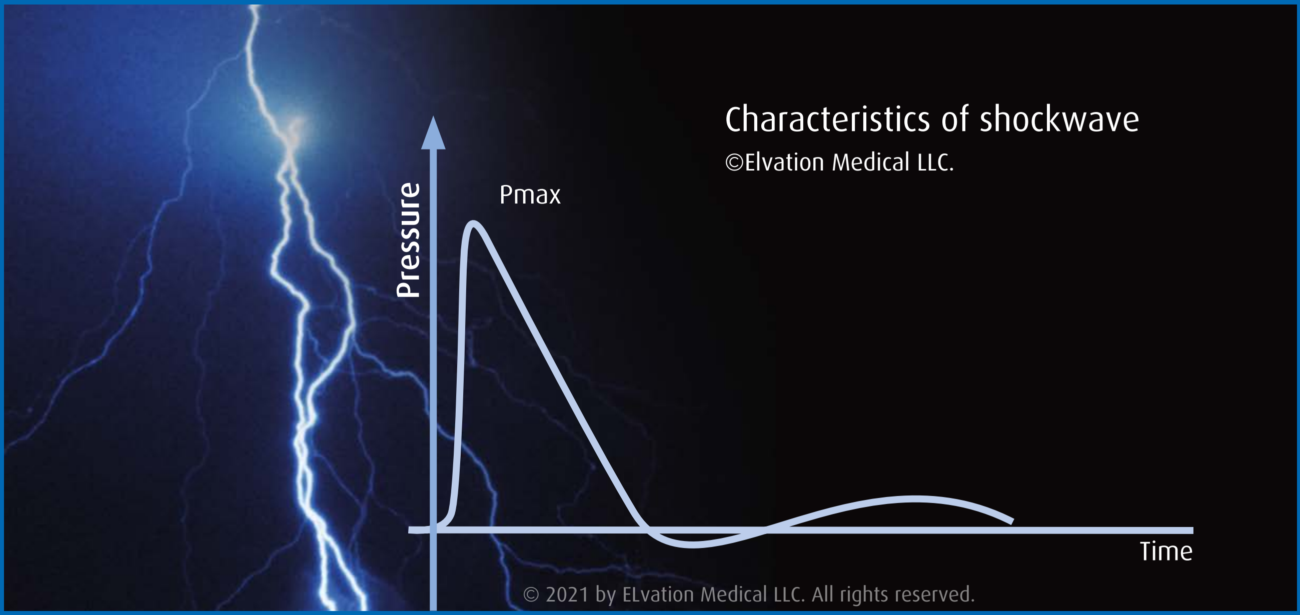


Figure 1 - physical characteristics of a shockwave.

Physical characteristics of a shockwave include[6]:

- A single pulse high pressure wave
- High peak pressure, up to and above 100 MPa
- Short rise time and steep slope that occurs in nanoseconds
- Followed by a negative pressure, low tensile wave
- Small pulse width, both pressure waves occur over about 5-10 microseconds

Technologies used to generate shockwaves

Focused shockwave

Several different focused shockwave systems are now available: electrohydraulic, electromagnetic, and piezoelectric. They all create true shockwave characteristics (Figure 1). The technologies differ in terms of how the shockwave is generated, and other associated properties such as noise level, focal size, durability of the therapy source, adjustment and focusing of the shockwave, penetration depth, and shockwave intensity.

Electrohydraulic shockwave

Electrohydraulic systems use a spark plug to produce the shockwaves (Figure 2) and reflectors to focus them, thus termed "indirect focusing". The intensity of shockwaves produced by these systems decrease over time making it often necessary to refurbish the therapy sources after around 50 treatments. Electrohydraulic systems also have different shaped therapy sources for different penetration depths. Treatments with this modality are loud, can be painful, and may require horses to be sedated.

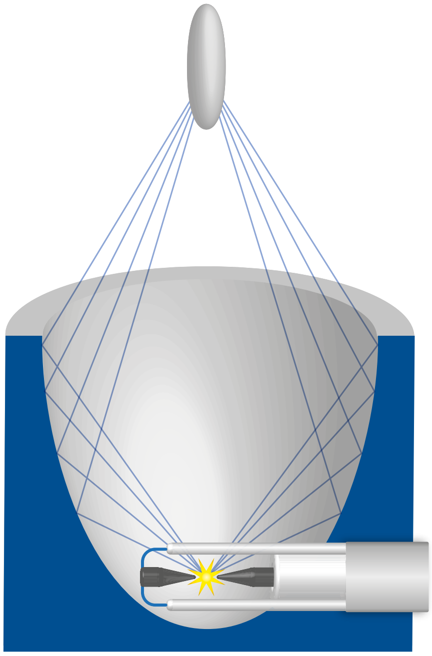


Figure 2 - Electrohydraulic shockwave.

Electromagnetic shockwave

Electromagnetic systems utilize an electromagnetic coil with a metal membrane next to the coil. The metal membrane produces acoustic pulses in response to the electromagnetic energy from the coil. The energy is then focused by an acoustic lens, thus termed "indirect focusing". They produce fairly consistent levels of peak energy and are not as loud as electrohydraulic systems. Electromagnetic shockwave systems do require different therapy sources to generate different length focal zones.

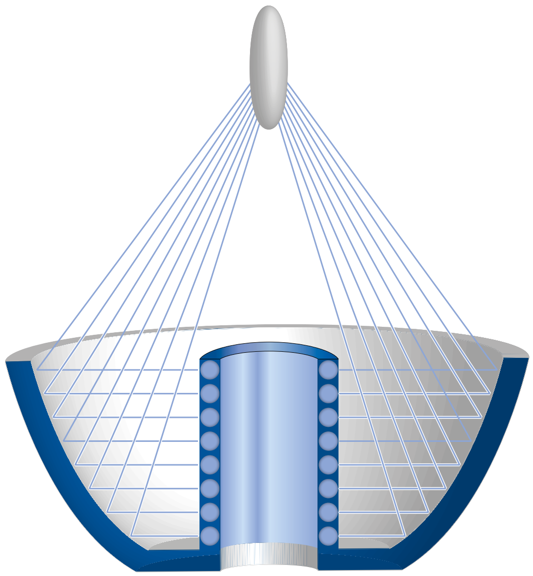


Figure 3 - Electromagnetic shockwave.

Piezoelectric shockwave:
The focused piezoelectric principle of the PiezoWave[2]

In a piezoelectric shockwave, a high-voltage pulse is used to excite piezoceramic elements arranged on a concave surface. This concave surface is termed the transducer and is located on the top of the handle of the therapy source for the shockwave. The unique physical characteristic of piezoceramic elements causes them to briefly and simultaneously expand by a few micrometers and create a pressure pulse. The piezo elements are precisely aligned so that each of the individual pressure pulses being produced come together at a defined point in tissue to create a shockwave . Piezo shockwave is the only shockwave method to use "direct focusing;" it does not require an additional reflector. The transducer of the therapy source is flat and compact and provides a precise well-defined focal zone (page 8). Different gel pads are used to adjust the penetration depth within tissues (page 10).

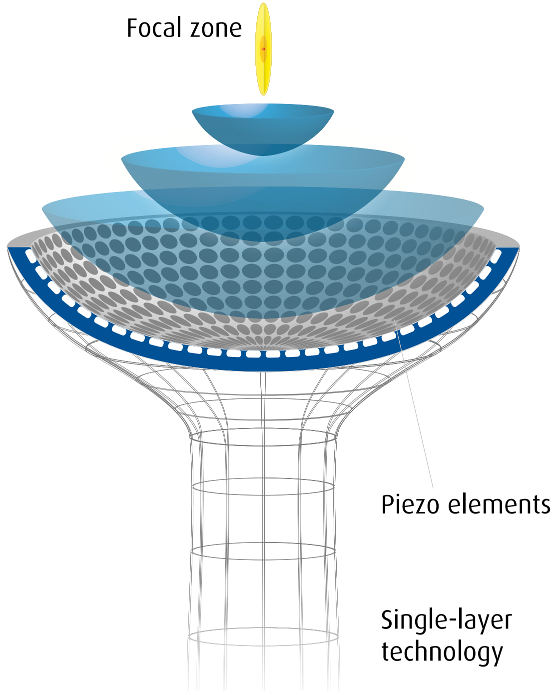


Figure 4 - Piezoelectric shockwave.

Piezo shockwave technology is known for its exceptional durability. Piezoelectric therapy sources often have a working life of more than 5,000 treatments, a significantly longer lifespan than both electrohydraulic and electromagnetic systems.

Therapy Source Components

- 1.1 Therapy Source handle with start/stop button
- 1.2 Plug connector
- 1.3 Identification plate with reference and serial numbers
- 1.4 Cord that transfers high voltage to piezo elements
- 1.5 Concave transducer that contains the piezo elements
- 1.6 Twist lock ring to hold gel pad in place
- 1.7 Gel pad (interchangeable)

Figure 5 - The PiezoWave² therapy source.

The PiezoWave² therapy sources disconnect from the control unit and include: the plug connector, an identification plate with reference and serial numbers, the cord that transfers high voltage to piezo elements, the handle with a start/stop button, the concave transducer that contains the piezo elements, and a twist lock ring to hold gel pad securely in place.

Piezo shockwave therapy sources are available with single-layer or double-layer technology. This technology is unique in that it can provide many different possibilities of focal zones including larger and/or different shaped focal volume, and/or deeper penetration.

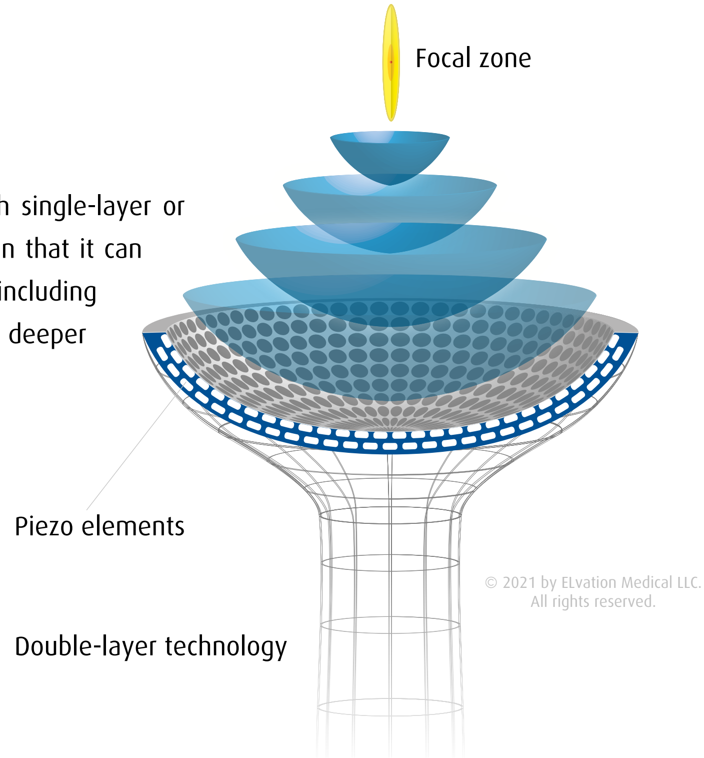


Figure 6 - The double-layer therapy source.

Focal zone, focal size, and specifications of PiezoWave[2]

The focal zone is the area in which the slope of the pressure waves steepen to create a shockwave. Because it is necessary for the shockwave to reach the specific location of the damaged tissue, the focal zone plays a key role in shockwave treatments. ElvationUSA provides five different piezo shockwave therapy sources (sold separately). Each therapy source has a different geometric shape, number of layers, and arrangement of piezo ceramics in its transducer. It is these specifics that create unique focal zones with different characteristics (Figure 11 and Figure 12). The standard terms used to describe the basics of shockwave and focal size of different shockwave modalities can be confusing and are often used randomly or incorrectly in advertising. It is important to understand these terms and be aware of the standards used to describe focal zones (Figure 7).

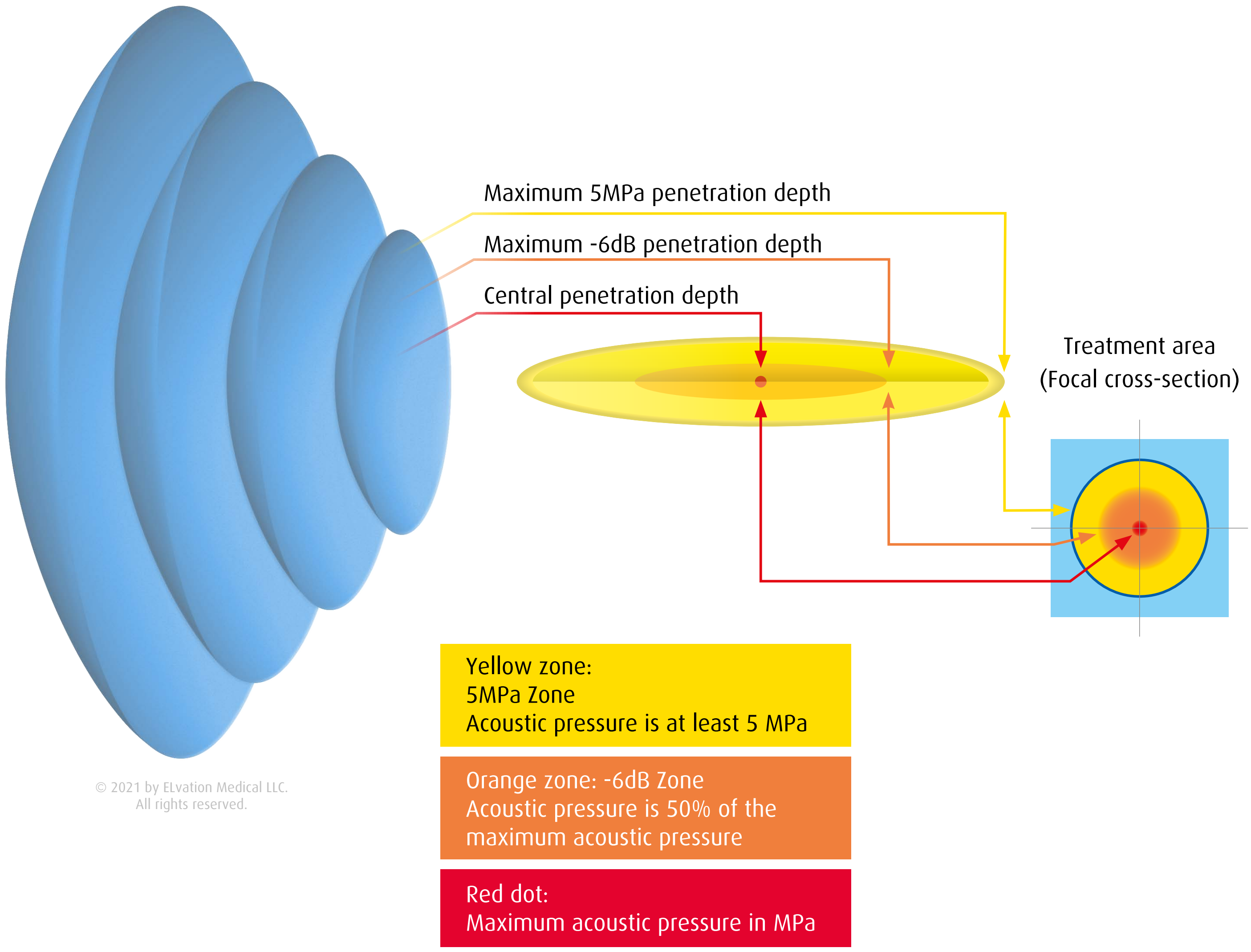


Figure 7 - Description of the focal zone.

The -6dB zone, which is often used for comparisons between measurements in studies, refers to the part of the focal zone where the acoustic pressure amplitude is at least 50% of the maximum amplitude achieved at the center of the focus. Based on the assumption that an acoustic pressure amplitude of at least 5MPa is required to achieve a biologic effect in tissue, the 5MPa zone is increasingly considered to be the therapeutic impact zone. The 5MPa zone is defined as the focal area in an acoustic field where the acoustic pressure amplitude is ≥ 5MPa. The central penetration depth is the distance between the skin's surface and the point of maximum acoustic pressure when using a gel pad which allows the greatest penetration depth. The distal penetration depth of the -6dB zone or 5MPa zone refers to the distance between the skin's surface and the distal "end" of the focal zone when using the gel pad which allows the greatest penetration depth. The penetration depth can be adjusted by using gel pads as spacers. The maximum applied energy flux density (EFD), a local variable for the acoustic pressure signal measured at the central focal point, is an acoustic field parameter often used to help standardize protocols in clinical practice and scientific studies.

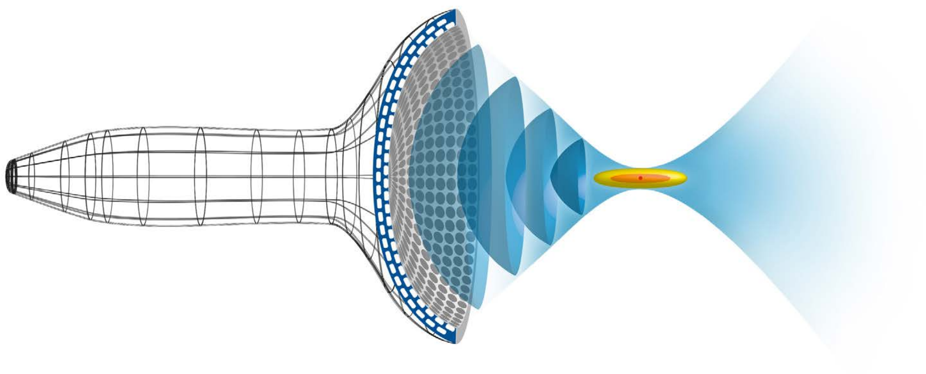


Figure 8 - Example of piezoelectric direct focusing design (no reflectors required).

Penetration depth of PiezoWave²

Piezo shockwave enables pinpoint and precise energy delivered during diagnosis and treatment because the guidelines 'penetration depth', 'intensity' and 'angle of entry' can be preselected independently of one another. When applying focused shockwaves the greatest pressure is created in the focal zone. Thus, targeted defined penetration depths with independently adjustable energy intensity are important and unique characteristics of focused piezo shockwaves.

Figure 9 - Therapy source penetration depth with different gel pads.

PiezoWave² therapy sources use exchangeable gel pads to ensure that the pulses reach the desired depth precisely and with as little scattering as possible (Figure 9). They are used as spacers and change the penetration depth in increments of 5 mm and 10 mm. The gel pads are designed to ensure that the virtual extensions of the cone-shaped exterior surfaces intersect precisely at the point of focus.

The central penetration depth ranges from 20 mm to 100 mm, with the distal penetration depth of 30 mm to 172 mm, depending on the choice of therapy source. The numbers on the gel pads show the penetration depth of the respective therapy source in mm (Figure 20).

Figure 10 - Gel on transducer under the gel pad (left) and line and dot on gel pad help for positioning (right).

Shockwave gel must be applied to the middle of the therapy source (Figure 10). When positioning the gel pad, any air bubbles can be eliminated by turning the gel pad.

ElvationUSA sells the Litohclear gel as its recommended coupling agent because it has less air bubbles. However, any water soluble ultrasound gel can be used as a coupling agent.

Therapy sources for PiezoWave² equine use

In veterinary medicine, focal zone ranges are from 20 mm to 100 mm in central penetration depth and 30 mm to 172 mm in distal penetration depth. Treatments can be optimized by choosing the therapy source to allow accurate application to the location of the target tissue.

The different therapy sources most commonly used for equine treatments are the F10G10, the FB10G6, and the F10G4. Each has different and unique properties in terms of focal zones and EFD levels (Figure 11). Energy flux density, EFD, is a measurement of energy passing through the central penetration depth of the focal zone.

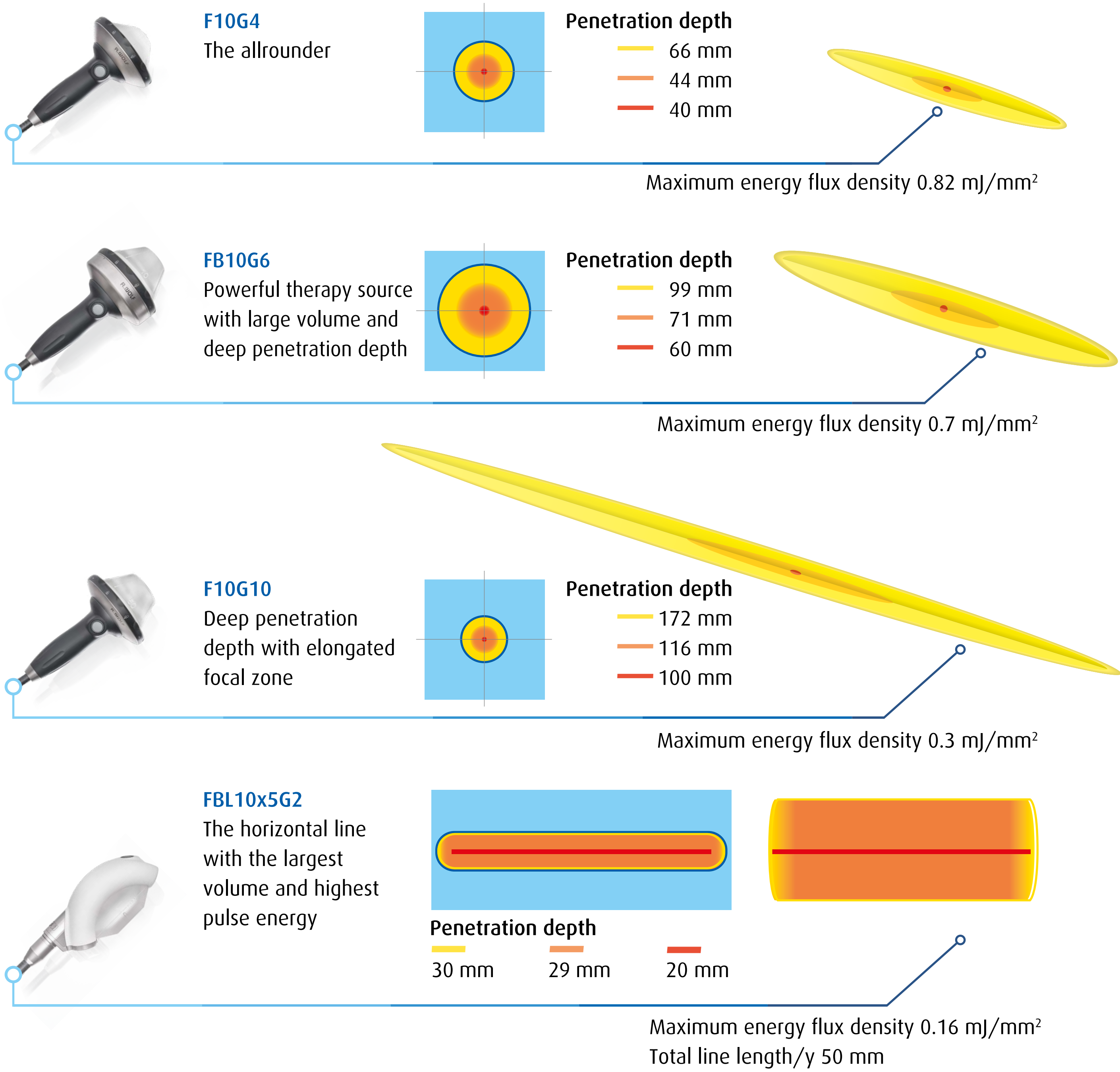


Figure 11- Therapy sources frequently used for equine patients.

Therapy sources for PiezoWave^2 equine use (continued)

Specific therapy sources are chosen based on patient population and intended therapeutic use of the technology. The FB10G6 has high energy, in comparison to the F10G10 that has the deepest penetration depth. The F10G4 has high energy but only a 40 mm central penetration depth that can be limiting when treating the axial skeletal region of a large horse. The F10G4 is often chosen by mixed animal practices that want to invest in a single therapy source to use on both small and large animals.

Level	F10/G4 Energy flux density (mJ/mm^2)	FB10/G6 Energy flux density (mJ/mm^2)	BL10x5G2 Energy flux density (mJ/mm^2)	F10G10 Energy flux density (mJ/mm^2)
0.1 - 1	0.032- 0.092	0.027-0.075	0.018	0.031
2	0.113	0.088	0.021	0.035
3	0.138	0.111	0.027	0.044
4	0.153	0.124	0.029	0.051
5	0.182	0.142	0.034	0.058
6	0.220	0.168	0.041	0.071
7	0.238	0.187	0.046	0.076
8	0.270	0.213	0.051	0.085
9	0.320	0.242	0.060	0.100
10	0.351	0.266	0.064	0.114
11	0.388	0.291	0.069	0.121
12	0.456	0.341	0.079	0.142
13	0.478	0.377	0.087	0.153
14	0.516	0.393	0.097	0.168
15	0.581	0.461	0.106	0.190
16	0.601	0.483	0.113	0.205
17	0.646	0.519	0.126	0.231
18	0.654	0.599	0.139	0.244
19	0.770	0.628	0.147	0.259
20	0.822	0.702	0.160	0.323

Figure 12 – EFD values per control unit settings starting with 0.1-0.9 up to 20.

Use of PiezoWave2 in equine veterinary medicine

Shockwaves are mechanical stressors which induce biochemical changes in living tissue[3]. Mechanical stimuli affect almost all cellular functions in living tissue, including growth, cell differentiation, cell migration, protein synthesis, physiological apoptosis, and tissue necrosis[7]. On a molecular level, the biochemical changes ultimately affect the gene expression of cells by eliciting specific tissue reactions[8]. Below is a list of specifically studied effects of shockwave.

- Stimulates new blood vessel formation [9,10,11]
- Regulates inflammation [12]
- Releases nitrogen monoxide (NO) which contributes to vasodilation, increases metabolic activity and angiogenesis, and exerts an anti-inflammatory effect [9]
- Changes levels of Substance P [13]
- Stimulates bone metabolism [14]
- Releases growth factors: IGF, TGFbeta, VEGFgamma [15,16,17]
- Exhibits chondroprotective effects [18]
- Dissolution of calcified fibroblasts [19]
- Stimulates lubricin production [20]
- Stimulates stem cells [21]
- Antibacterial effects [22]

Use of PiezoWave^2 in equine veterinary medicine (continued)

The treatment of orthopedic disorders plays an important role in equine sports medicine. Shockwave is one of the few medical technologies that treats pain syndromes of the musculoskeletal system by repeatedly triggering the body's own self-healing processes[3]. There are many studies that describe the use and verify the efficacy of shockwave for healing of both bone and soft tissue in equine veterinary medicine [5, 23-30]. Shockwaves are able to stimulate the endogenous production of lubricin in the tendons and at tendon insertions[20]. Lubricin helps tendons slide within joints and an increased amount of lubricin could provide pain relief and decreased joint erosion and account for some of the clinical success of shockwave when treating chronic osteoarthritis. The efficacy of shockwave for trigger point treatment and the effectiveness of focused piezo shockwaves has also been studied [30,31].

A representation of conditions piezoelectric shockwave can be used to treat in equine veterinary medicine are listed below. More information can be found in the remainder of this document.

- Tendon and ligament injuries and desmitis
- Chronic or acute proximal suspensory disease
- Osteoarthritis
- Back, neck, and sacral myofascial pain
- Navicular pain
- Bone healing
- Wounds

Section 1 References

1. (2020) Shockwave History. The International Society for Medical Shockwave Treatment. https://www.shockwavetherapy.org/about-eswt/shockwave-history/
2. Haupt, G. (1997). Use of extracorporeal shock waves in the treatment of pseudarthrosis, tendinopathy and other orthopedic diseases. The Journal of urology, 158(1), 4-11.
3. Wang, C. J. (2012). Extracorporeal shockwave therapy in musculoskeletal disorders. Journal of orthopaedic surgery and research, 7(1), 1-8.
4. Saggini, R., et al. (2015). Clinical application of shock wave therapy in musculoskeletal disorders: Part I. J Biol Regul Homeost Agents, 29(3), 533-45.
5. McClure, S., & Weinberger, T. (2003). Extracorporeal shock wave therapy: clinical applications and regulation. Clinical techniques in equine practice, 2(4), 358-367.
6. (2020) Physical principles of ESWT. The International Society for Medical Shockwave Treatment. https://www.shockwavetherapy.org/about-eswt/shockwave-history/
7. Wang, J. H., & Li, B. (2010). Mechanics rules cell biology. BMC Sports Science, Medicine and Rehabilitation, 2(1), 1-7.
8. Neuland H.G., Duchstein H.J. (2006) Manifestation Pattern of the Extracorporeal Shock Wave Therapy Using Mechanotransduction. Orthopaedische Praxis. 42: 4.
9. Yan, X., et al. (2008). Improvement of blood flow, expression of nitric oxide, and vascular endothelial growth factor by low-energy shockwave therapy in random-pattern skin flap model. Annals of plastic surgery, 61(6), 646-653.
10. Wang, C. J., et al. (2009). Extracorporeal shockwave treatment for chronic diabetic foot ulcers. Journal of surgical research, 152(1), 96-103.
11. Wang, C. J., et al. (2003). Shock wave therapy induces neovascularization at the tendon–bone junction. A study in rabbits. Journal of Orthopaedic Research, 21(6), 984-989.
12. Ciampa, A. R., et al. (2005). Nitric oxide mediates anti-inflammatory action of extracorporeal shock waves. FEBS letters, 579(30), 6839-6845.
13. Maier, M., et al. (2003). Substance P and prostaglandin E2 release after shock wave application to the rabbit femur. Clinical Orthopaedics and Related Research (1976-2007), 406(1), 237-245.
14. Muzio, G., et al. (2010). Shock waves induce activity of human osteoblast-like cells in bioactive scaffolds. Journal of Trauma and Acute Care Surgery, 68(6), 1439-1444. Atesok, K., et al. (2014). Augmentation of tendon-to-bone healing. JBJS, 96(6), 513-521.
15. Atesok, K., et al. (2014). Augmentation of tendon-to-bone healing. JBJS, 96(6), 513-521.
16. Berta, L., et al. (2009). Extracorporeal shock waves enhance normal fibroblast proliferation in vitro and activate mRNA expression for TGF-β 1 and for collagen types I and III. Acta orthopaedica, 80(5), 612-617.
17. Chen, Y. J., et al (2004). Extracorporeal shock waves promote healing of collagenaseβ induced Achilles tendinitis and increase TGFβ β 1 and IGFβ I expression. Journal of Orthopaedic Research, 22(4), 854-861.

Section 1 References (continued)

18. Zhao, Z., et al. (2012). Extracorporeal shock-wave therapy reduces progression of knee osteoarthritis in rabbits by reducing nitric oxide level and chondrocyte apoptosis. Archives of orthopaedic and trauma surgery, 132(11), 1547-1553.
19. Ioppolo, F., et al. (2013). Clinical improvement and resorption of calcifications in calcific tendinitis of the shoulder after shock wave therapy at 6 months' follow-up: a systematic review and meta-analysis. Archives of physical medicine and rehabilitation, 94(9), 1699-1706.
20. Zhang, D., et al. (2011). Extracorporeal shockwave-induced expression of lubricin in tendons and septa. Cell and tissue research, 346(2), 255-262.
21. Neuland, H. G., Schmidt, A. (2006) Induction of adult (tissue-specific) mesenchymal stem cells through extracorporeal shock waves to regenerate muscoskeletal Tissue. Orthopaedische Praxis. 42: 4.
22. Horn, C., et al. (2009). The effect of antibacterial acting extracorporeal shockwaves on bacterial cell integrity. Medical Science Monitor, 15(12), BR364-BR369.
23. Dyson, S. J. (1995). Proximal suspensory desmitis in the hindlimb. Equine Veterinary Education, 7(5), 275-278.
24. Bischofberger, A. S., et al. (2006). Histomorphologic evaluation of extracorporeal shock wave therapy of the fourth metatarsal bone and the origin of the suspensory ligament in horses without lameness. American journal of veterinary research, 67(4), 577-582.
25. Frisbie, D. D., et al. (2009). Evaluation of the effect of extracorporeal shock wave treatment on experimentally induced osteoarthritis in middle carpal joints of horses. American journal of veterinary research, 70(4), 449-454.
26. Kawcak, C. E., et al. (2011). Effects of extracorporeal shock wave therapy and polysulfated glycosaminoglycan treatment on subchondral bone, serum biomarkers, and synovial fluid biomarkers in horses with induced osteoarthritis. American journal of veterinary research, 72(6), 772-779.
27. Dahlberg, J. A., et al. (2006). Force platform evaluation of lameness severity following extracorporeal shock wave therapy in horses with unilateral forelimb lameness. Journal of the American Veterinary Medical Association, 229(1), 100-103.
28. Bar, K., et al. (2001) Extracorporeal shockwave therapy- a remedial procedure for navicular disease. Tierarzti. Prax. 29 (G), 1-5.
29. McClure, S.R., et al. (2004a) Extracorporeal shock wave therapy for treatment of navicular syndrome. In: Proc. 50th Ann. Convention of the Amer. Ass. of Equine Practitioners, Denver, Colorado, Dec. 4-8, p. 316-319.
30. Jeon, et al. (2012). The effect of extracorporeal shock wave therapy on myofascial pain syndrome. Annals of rehabilitation medicine, 36(5), 665-674.
31. Yang, Y-J., et al (2014) Pressure pain threshold and visual analogue scale changes in high and low energy extracorporeal shock wave. Physical Therapy Rehabilitation Science. 3 (2): 142-147. Doi: 10.14474/ ptrs.2014.3.2.142.

Section 2 - Clinical use of the PiezoWave²

Piezo technology - key characteristics

- Direct focusing technology (precisely defined, perfect for localizing and treating pain points)
- Precisely adjustable penetration depth
- Penetration depth and intensity settings can be adjusted independently
- No pain at the interface between patient and device
- Variable intensity settings for improved patient comfort
- High-volume, linear-focused therapy source: perfect for uniform applications
- Very long lifespan
- Quiet and tolerable to minimize the animal´s flight instinct and avoid the necessity for sedation in most cases
- Excellent massage effect, even for deep myofascial structures

Safety and adverse effects

Since 1998, thousands of veterinary patients have been treated with focused shockwaves. Original use of fESWT for horses was for osteoarthritis, insertional desmopathies, and stimulation of osteogenesis [1,2,3,4]. Continued research activity on shockwave therapy is expanding its application across multiple species and revealing its biomechanical mechanisms of action[5].

More recently, fESWT has been used to treat tendon and ligament damage along with muscle pain [6,7,8,9]. Generally, treatment side effects reported in literature are minimal with some variation based on the type of the shockwave device being used and the intensity of shockwave treatment being delivered.

Although the use of piezoelectric fESWT has only recently been documented in veterinary literature[10], there are a significant number of human studies using the piezoelectric technology for the treatment of acute and chronic musculoskeletal pain[11,12,13,14,15].

It is important that shockwave be performed by trained veterinary medical professionals that know when and where shockwave should and should not be used. The decision as to whether or not to carry out a planned application is the responsibility of the end-user and must be based on the patient's current condition.

Basic contradictions include:

- Areas of infection in the focal area
- Malignant tissue in the focal area
- Coagulation disorders (a prior check of the coagulation status may be necessary)
- Use in conjunction with blood-thinning medication
- Pregnancy, fetus near the focal area
- Lung tissue in the focal area
- Brain tissue or spinal cord in the focal area
- Eyes in the focal area
- Epiphyseal growth plate in the focal area

This device is intended to treat musculoskeletal tissue/diseases and the depth of penetration should be specified so that it cannot reach any organ.

Common equine clinical conditions treated with Piezowave[2]

Tendon and ligament damage

Tendons and ligaments are soft tissue structures that support the function/mobility of joints. They are composed of fibrous connective tissue that are organized into primary, secondary, and tertiary bundles of collagen fibrils surrounded by connective tissue. Tendons transfer load from muscle to bone and the contraction of these muscle and tendons provide joint mobility. Tendon and ligament damage may be caused by acute trauma, repetitive loading, gradual wear and tear from overuse, aging, or supportive muscle and fascial restrictions causing excess strain on the tendons (Figure 13).

Damage to these structures usually causes varying degrees of pain, inflammation, lameness, stiffness, and loss of strength in the affected joint. The lesion may be sore, warm, or swollen to the touch. In chronic issues, fibrotic scarring (fibrosis) may be palpated along the affected tendon or ligament or within the associated muscle and fascia. These injuries often limit the ability of sport horses to compete at the top level [16].

In animal models, fESWT (focused ESWT) has been shown to increase neovascularization at the tendon-bone junction and induce healing with an increase in TGF-beta1 and IGF-1 expression, along with stem cell recruitment [17,18]. However, to avoid any adverse effects both the amount of energy used in terms of EFD and the status of the tendon ligament tissue needs to be taken into consideration when using ESWT on tendons [18,19,20]. On horses with induced lesions in the body of the suspensory ligament or in the body of the SDFT, fESWT was shown to enhance healing at an energy of about 0.14 mJ/mm^2 [6,7,21]. This suggests 0.14 mJ/mm^2 is an appropriate upper boundary for the amount of energy needed to heal an acute soft tissue injury.

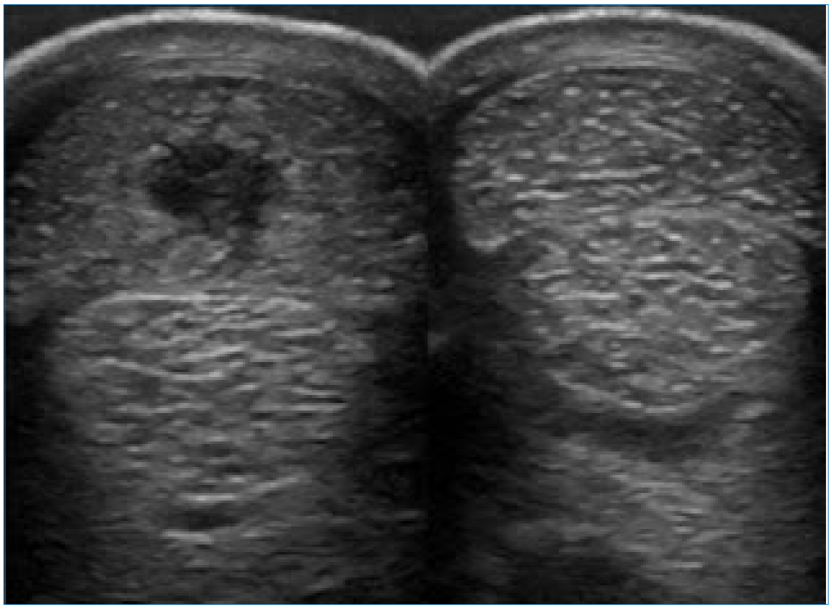


Figure 13 - Ultrasound image of a core lesion in SDFT tendon.

Proximal suspensory desmitis

Proximal suspensory desmitis (PSD) is a common cause of both fore and hindlimb lameness is sport horses [21]. The proximal suspensory attaches to the proximal palmar edge of the cannon bone; in the front limb it is just distal to the carpus and in the hind limb it is just distal the hock. PSD is difficult to treat as often both the ligament and boney attachment are involved. PSD can occur from either an acute injury or recurring stress on the ligament causing a chronic condition. Shockwave promotes healing of both bone and ligament [23,24,25]. It has also been shown to reduce pain at the bone-ligament interface [26]. Equine studies on induced suspensory injuries indicate shockwave is helpful in healing of suspensory desmitis [6,7,21]. Shockwave is now a common treatment used for proximal suspensory injuries that often involve both bone and ligament damage.

Figure 14 - MRI image of an injured proximal hind suspensory.

Osteoarthritis

Osteoarthritis, OA, is the progressive deterioration of the articular cartilage of diarthrodial (synovial) joints mainly due to secondary causes such as: trauma, infection, immune-mediated diseases, developmental malformations, joint instability, repeated abnormal activity, etc. OA is characterized by hyaline cartilage thinning, joint effusion, and periarticular osteophyte formation. Clinical signs of OA include lameness, pain, joint swelling, muscle atrophy, peri-capsular fibrosis, reduced joint range of motion, and crepitation. Treatment goals are to control pain, improve joint function and mobility, delay the progression of disease, and promote the quality of life. Shockwave provides rapid and long-lasting pain relief in OA patients by regulating proinflammatory cytokines, promoting the proliferation and regeneration of cartilage tissues, and stimulating lubricin production. In a rat model, fESWT on the medial condyle of the stifle increased bone strength and decreased the progression of OA histologically and radiographically [27]. Equine clinical studies on induced OA demonstrate improvement in lameness after ESWT treatment, but do not find notable changes in radiographs or joint components including cellular membranes, joint fluid, and cartilage [1,28]. In a more recent study that also monitored serum and synovial fluid biomarkers after ESWT of carpi with induced OA, the serum osteocalcin concentration was increased indicating that bone remodeling had started [29]. These studies support fESWT as a viable treatment to improve pain and function for horses with lameness from OA [1,28,29].

fESWT is a viable treatment to improve pain and function for horses with lameness from OA; however, the disease modifying effects have not been well documented in horses.

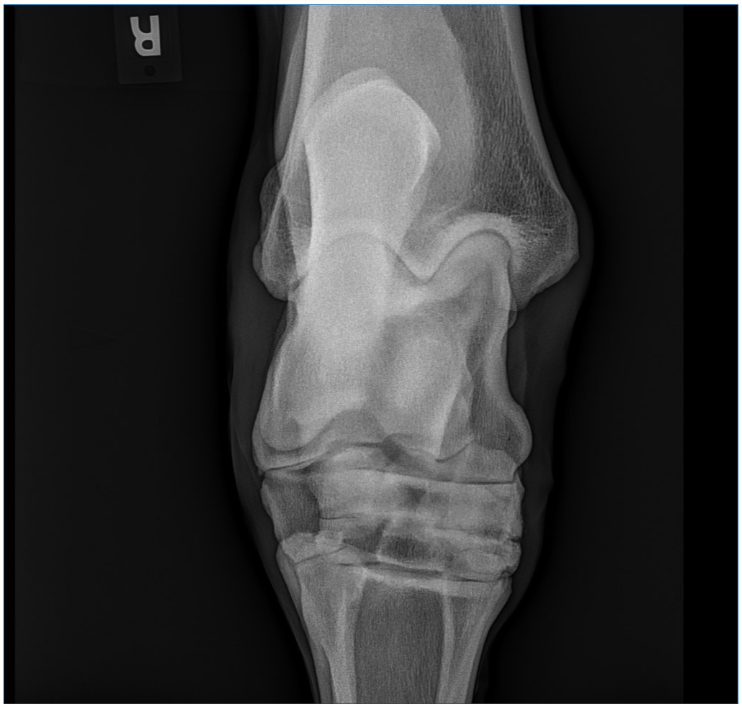


Figure 15 - Radiograph of a hock with significant osteoarthritis.

Foot pain

Foot pain in horses can be caused by various conditions including but not limited to: laminitis, coffin joint OA, sole bruising, collateral ligament damage, caudal heel pain or navicular syndrome. Some but not all of these conditions can be effectively treated with fESWT. Caudal heel pain itself can be associate with various structures within the area including osseous changes in the navicular bone, inflammation in the navicular bursa, damage to the distal region of the deep digital flexor tendon with or without involvement of its attachment to the navicular bone. The use of focused fESWT for caudal heel pain has been shown to have a positive analgesic effect at various different time points, from 2 to 128 days post therapy [30,31,32,33].

However, neither radiographic nor MRI imaging have identified structural changes associated with the analgesic effect [30,32]. The complexity of the navicular apparatus, its associated structures and how each affects the function of the equine movement makes determining the mechanism of pain relief in the caudal heel by focused shockwave very difficult. However, fESWT does provide analgesia for horses exhibiting caudal heel pain and has become a usual treatment for competitive equine athletes. With the PiezoWave it is recommended to identify what structures in the area are the cause of the pain so biologic healing can be supported. Coffin joint OA is another cause of foot pain that can be treated with fESWT. There is clinical evidence that fESWT helps with OA as presented in the previous section. Although no published data exists for the use on the equine coffin joint, there is anecdotal evidence for treating the coffin joint.

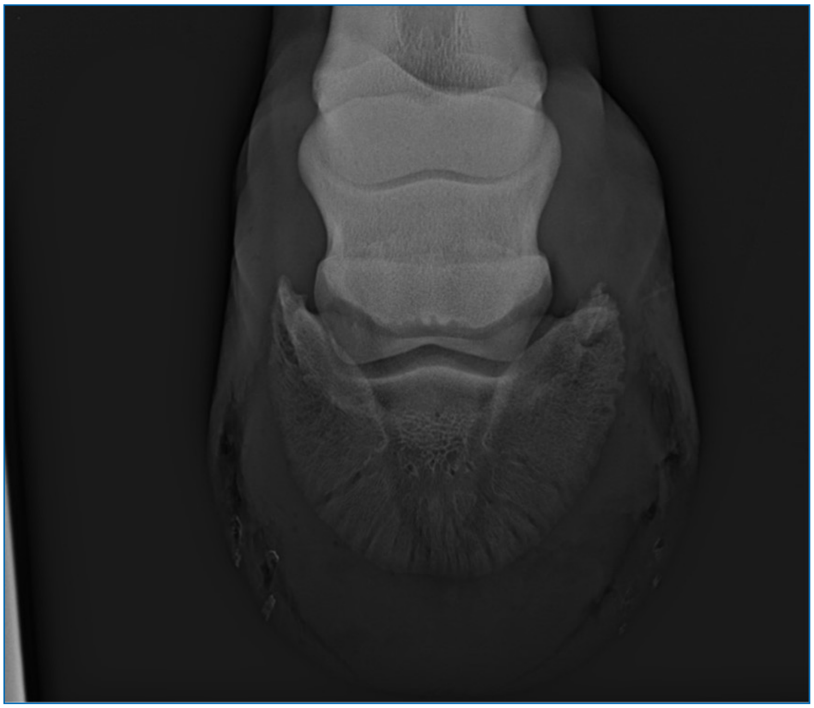


Figure 16 - Radiograph of navicular disease, navicular disease can be a cause of caudal heal pain.

Back, neck, and sacral pain

Pain associated with the equine axial skeleton can occur from issues with the osseous structures, soft tissue components, as well as the central or peripheral nervous system. This pain can occur in the cervical, thoracic, lumbar, or sacral areas and can cause associated gait lameness, poor performance, and/or avoidance behaviors in equine athletes. The previous section discussed the use of fESWT on OA. OA can also occur at different locations along the spine within the individual facet joints. Pain from OA in the spine is frequently helped with fESWT treatments. Decreased cervical pain and increased range of motion has been demonstrated with fESWT in humans with myofascial pain syndrome [34].

fESWT was shown to have a positive effect on nuchal ligament desmopathy in horses [3]. A recent study demonstrated that the mechanical nociceptive threshold was increased in horses that had pain between T12 and L5 with the use of fESWT [9]. Pain relating to the sacroilliac joint area in horses is often treated with fESWT. When working with the axial skeletal areas of horses, a proper diagnosis of the primary injury is needed. Due to the pain ascending tracts of the pathway, pain (or nociception) can be referred to a secondary area and treatment of this area will not provide lasting relief or stimulate healing of the appropriate tissue.

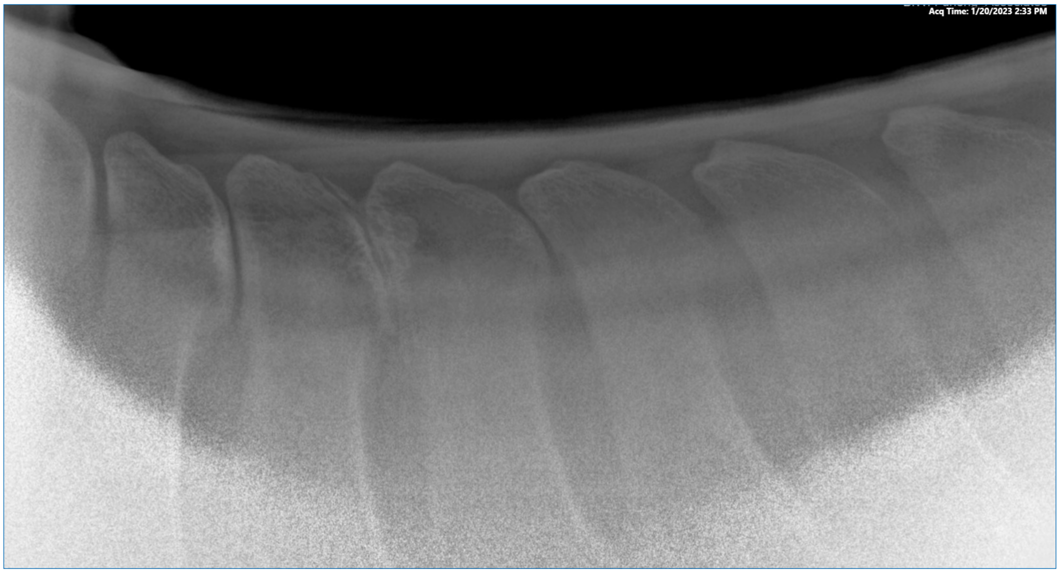


Figure 17 - Radiograph of kissing spine, kissing spine can be a primary cause of significant back pain.

General treatment information

Patient preparation

The acoustic pulses generated in the transducer of the therapy source require a liquid medium to travel through. This is created by the gel pad, coupling gel, and water. Very long, thick coat hair may need to be trimmed before starting treatment. Moisten the area to be treated generously with water e.g. with the aid of a spray bottle and apply sufficient coupling gel. Avoid excess hair and air bubbles to ensure that the acoustic pulses will be properly transmitted to the target area.

Sedation

PiezoWave² therapy is usually very well tolerated by horses, making sedation often unnecessary. At the start of every therapy, it is important to gradually accustom the animal to treatment, which means starting at a low intensity and gradually increasing the intensity. It is important to pay attention to any signs of pain or defensive movements by the patient and adjust the intensity accordingly.

Figure 18 – PiezoWave² as a calm, comfortable treatment process.

Determining treatment guidelines

Treatment parameters (settings on control unit and choice of depth adjustment with gel pads) are based on each individual patient and the condition being treated. These unique and changing patient characteristics are matched by the PiezoWave^2 parameter adjustability. Clinicians choose a starting point- estimating depth of penetration and setting intensity/frequency that introduce the patient to the feeling of the pressure pulse and then adjust them based on patient cues like relaxed yawning, licking or chewing, and leaning into the therapy source; as these are indications that the parameters are appropriately set.

Therapy source

To optimize the therapeutic results, the user should understand the characteristics of and choose the best therapy source for each situation. A review of specific therapy sources is in Section 1 - Therapy sources for PiezoWave^2 equine use (page 12).

Figure 19 - The F10G6 and the F10G10 are the most commonly used therapy sources for equine therapy.

Gel pad

With Piezowave[2]'s site-specific focused energy, it is important to choose the appropriate gel pad for the correct depth of penetration (page 10).

Figure 20 - The numbers on the gel pads represent central penetration depth in mm.

It is best to use a combination of manual palpation and diagnostic imaging to determine the area of damaged tissue, the depth of penetration required to reach it, and the optimal angle of entry for the therapy source. If imaging is not possible, the correct gel pad can be chosen based on knowledge of the anatomy, and the ability of the PiezoWave[2] to scan for and flare pain points that are identified by the patient's bio feedback. When treating different anatomical structures in one session, it may be necessary to use multiple different gel pads.

Pulse frequency

Current literature does not define a biological response to variations of pulse frequency (pulses/second, Hz). Pulse frequency is adjusted primarily to help make the treatment more tolerable for the patient. Starting with a lower setting, such as 4-5, and increasing to tolerance while looking for pain and biologic response is best. In some patients, a higher frequency can be more painful; while in others, a higher frequency is less painful.

Figure 21 - The left plus and minus keys are used to set the pulse frequency from 0-12.

Dosing - EFD and number of pulses

Energy flux density, EFD, values are a means to quantify treatment intensity and standardize treatments, especially when comparing energy from different shockwave sources. It is evident that, due to acoustic impedance, different tissue types require different amounts of energy to initiate mechanotransduction and trigger the biological effect of shockwave.

Effective energy levels are patient and injury dependent; therefore, energy levels applied are primarily guided by the patient's treatment tolerance. Variations in injury type, stage of the injury, as well as individual patient pain tolerance result in the ranges of recommended treatment values in this document. Assessing patient outcomes and treatment progression can also guide energy intensity. Patients often tolerate more energy as the healing process progresses.

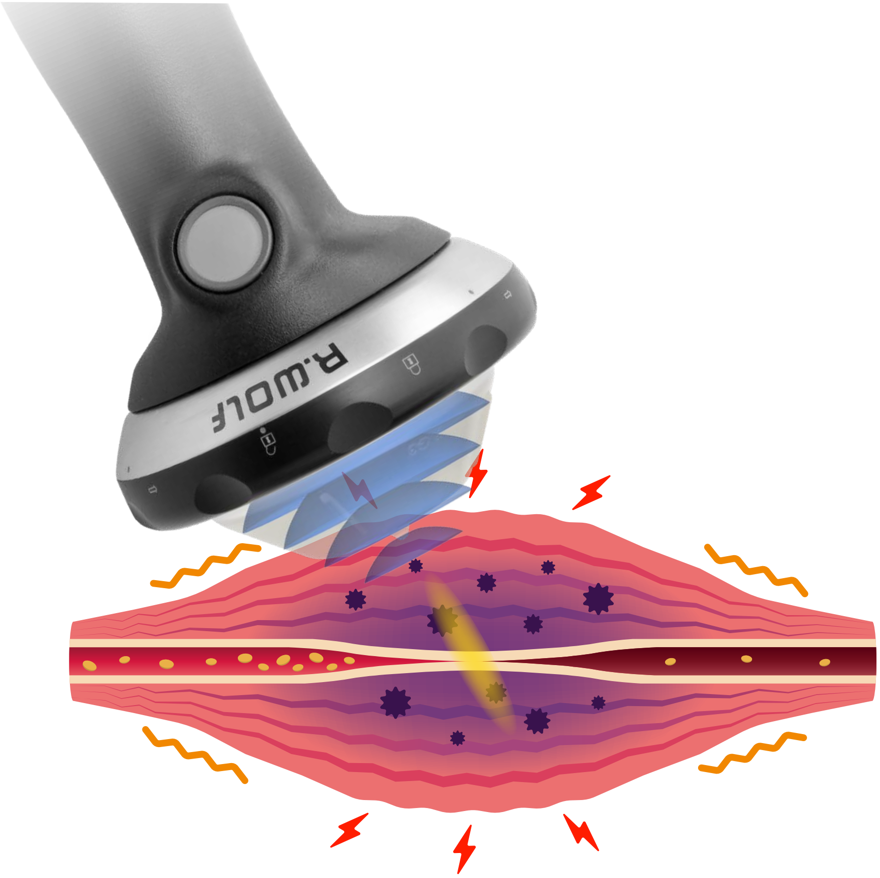


Figure 22 - A representation of the PiezoWave² focal zone within inflamed tissue.

Dosing - EFD and number of pulses (continued)

When treating similar clinical conditions, individual patients have different sensitivity to the shockwave energy. This document supplies suggested ranges of energy levels with which our users have seen positive results. In general, it is important to start the therapy with low energy and work up according to the patient's tolerance paying attention the animal's cues. The energy flux density tolerated by each patient may also be affected by the method in which the therapy source is being moved and positioned during the treatment session. When the energy engages injured tissue it can become painful to the patient and the operator may need to decrease the power intensity to make the therapy tolerable.

The total number of pulses for treatment of a specific conditions is case dependent. Since the amount of energy needed to create mechanotransduction in the cells of patients has not been defined, the attending veterinary professional should evaluate the patient's response and adjust total number of pulses accordingly.

When determining the total number of pulses and recommended energy levels, it is important to understand that unlike when using lasers, **the energy is not accumulated in the tissue**. Each shockwave impulse triggers the tissue and is then converted into mechanical energy. Therefore, the quantity of pulses and energy flux density used must be enough to mechanically process the tissue.

Figure 23 - When treating similar medical conditions, individual patients have different sensitivities to shockwave energy.

Treatment schedule

Positive clinical results with the PiezoWave² can be seen after only one or two treatments. But for healing to occur, a schedule of once every 7-14 days for a total of 3-6 treatments is recommended. Weekly low energy treatments are useful during the initial therapy of acute injuries. In chronic conditions, after a series of treatments and with the pain under control, the frequency of treatments can be decreased to an as-needed basis. Scheduled re-evaluations should be used to determine if more PiezoWave² therapy is needed.

Figure 24 - Treatment schedules should be case specific with scheduled re-evaluations to monitor progress.

Technique for therapy application

It is important that the damaged tissue receives enough energy to stimulate a biological reaction (mechanotransduction). To get this optimal effectiveness from each treatment session the positioning of the therapy source, the therapist, and the animal are all important.

Movement and positioning of the therapy source should be accurate and precise. It is recommended that the therapist be in a comfortable position next to the pet with their dominant hand on the therapy source and the other hand on the pet feeling the surrounding tissue. The animal should also be in a comfortable position in which they can remain still and relaxed.

If the location of the damaged tissue is clearly identified, a static treatment can be used, and the therapy source is held at the location of the injury or moved a short length along the specific tendon or ligament. A small rocking of the therapy source and changing of the angle of entry can be used to slightly expand the area of treatment.

If large areas of muscles and fascia are being treated the therapy source is moved slowly over the area to apply energy through the tissue. If a reactive area is localized the therapy source can be held still over that area for 300-500 pulses with the purpose of initiating the process of mechanotransduction.

Figure 25 - A representation of the PiezoWave[2] focal zone with a small rocking of the therapy source.

Ultrasonic guidance

If ultrasound imaging is available, it should be used to identify the damaged tissue. It will also identify the best positioning of the PiezoWave² therapy source and the appropriate gel pad to be used. The optimal site and angle of entry for the therapy source is the same as that from which the sonographer receives the best diagnostic image.

PiezoWave² as a diagnostic tool

Sometimes the exact locations of pain points, whether the primary injury or secondary due to compensation, are not known. In these cases, the PiezoWave² can be used in a diagnostic manner to identify these sites by flaring the pain points. The therapy source is used in a dynamic technique and moved slowly over the suspected area beginning at a low energy intensity while carefully monitoring for the patient's reaction. If no reaction is seen, the intensity is gradually increased and the scan is repeated. When a specific pain point is identified via the animal's bio feedback, the therapy source is held stationary in that position for approximately 500 pulses. It may be useful to gently rock the therapy source at a specific site to provide a slight increase in treatment area. After therapy on a single point is complete the therapist can continue to slowly scan the area to locate another pain point and repeat the process.
If the patient is not tolerating the energy of the therapy needed to identify the pain point or flare the injured site, in most cases, the intensity level can be lowered to a tolerable level and positive results will still be seen.

Post treatment care

Early controlled movement acts as a stimulus on the healing areas and is essential for the recovery process. Excessively long rest periods result in structures atrophying, reduced metabolic activity, and can have a significant negative effect on the horse's psyche. A structured rehabilitation plan with a program of specific exercises can have a decisive impact on the successful outcome of therapy. Each horse's follow up care should be designed by a veterinary medical professional with re-evaluations to monitor the horse's progress. It is important to recognize there is an analgesic effect with shockwave and no horse should overstress the affected structures for at least 72 hours post treatment.

Figure 26 - Rehabilitation is an integral part of a successful treatment plan.

Section 2 references

1. McCarroll, G. D., et al (2000). Extracorporeal shock wave therapy for treatment of osteoarthritis of the tarsometatarsal and distal intertarsal joints of the horse. In Proceedings (pp. 200-202). 46th Annu Meet Am Assoc Equine Pract.
2. McCarroll, G. D., et al (2002). Initial experiences with extracorporeal shock wave therapy for treatment of bone spavin in horses–part II. Veterinary and Comparative Orthopaedics and Traumatology, 15(03), 184-186.
3. McClure, S., et al (2003). Extracorporeal shock wave therapy: clinical applications and regulation. Clinical techniques in equine practice, 2(4), 358-367.
4. Mcclure, S. R., et al. (2004). Effects of extracorporeal shock wave therapy on bone. Veterinary Surgery, 33(1), 40-48.
5. d'Agostino, M. C., et al (2015). Shock wave as biological therapeutic tool: From mechanical stimulation to recovery and healing, through mechanotransduction. International journal of surgery, 24, 147-153
6. McClure, S. R., et al. (2004). The effects of extracorporeal shock-wave therapy on the ultrasonographic and histologic appearance of collagenase-induced equine forelimb suspensory ligament desmitis. Ultrasound in medicine & biology, 30(4), 461-467.
7. Caminoto, E. H., et al. (2005). Ultrastructural and immunocytochemical evaluation of the effects of extracorporeal shock wave treatment in the hind limbs of horses with experimentally induced suspensory ligament desmitis. American journal of veterinary research, 66(5), 892-896.
8. MacKay, A. V., et al. (2020). Characterization of the use of shock wave therapy among equine veterinarians. The Canadian Veterinary Journal, 61(9), 990.
9. Trager, L. R., et al. (2020). Extracorporeal shockwave therapy raises mechanical nociceptive threshold in horses with thoracolumbar pain. Equine veterinary journal, 52(2), 250-257.
10. Owen, H. (2022). Case study: Treating infraspinatus and supraspinatus trigger points and supraspinatus tendinopathy utilizing piezoelectric shockwave. Frontiers in Veterinary Science, 9.
11. Yang, Y. J., et al. (2014). Pressure pain threshold and visual analogue scale changes in the high and low energy extracorporeal shock wave. Physical therapy rehabilitation science, 3(2), 142-147.
12. Lin, T. Y., et al. (2015). The efficacy of ultrasound-guided extracorporeal shockwave therapy in patients with cervical spondylosis and nuchal ligament calcification. The Kaohsiung Journal of Medical Sciences, 31(7), 337-343.
13. Albisetti, W., et al. (2010). Stress fractures of the base of the metatarsal bones in young trainee ballet dancers. International orthopaedics, 34(1), 51-55.
14. Chen, T. W., et al. (2014). The efficacy of shock wave therapy in patients with knee osteoarthritis and popliteal cyamella. The Kaohsiung journal of medical sciences, 30(7), 362-370.
15. Carlisi, E., et al. (2016). Focused extracorporeal shock wave therapy combined with supervised eccentric training for supraspinatus calcific tendinopathy. European journal of physical and rehabilitation medicine, 54(1), 41-47.
16. Goodship, A. E., et al. (1994). The pathobiology and repair of tendon and ligament injury. Veterinary Clinics of North America: Equine Practice, 10(2), 323-349.
17. Wang, C. J., et al. (2002). Shock wave-enhanced neovascularization at the tendon-bone junction: an experiment in dogs. The journal of foot and ankle surgery, 41(1), 16-22.
18. Chen, Y. J., et al (2004). Recruitment of mesenchymal stem cells and expression of TGF-β 1 and VEGF in the early stage of shock waveβ promoted bone regeneration of segmental defect in rats. Journal of orthopaedic research, 22(3), 526-534.

19. Rompe, J. D., et. al. (1998). Dose-related effects of shock waves on rabbit tendo Achillis: a sonographic and histological study. The Journal of bone and joint surgery. British volume, 80(3), 546-552.
20. Maier, M., et al. (2001). Impaired tensile strength after shock-wave application in an animal model of tendon calcification. Ultrasound in medicine & biology, 27(5), 665-671.
21. Giunta, K., et al. (2019). Prospective randomized comparison of platelet rich plasma to extracorporeal shockwave therapy for treatment of proximal suspensory pain in western performance horses. Research in veterinary science, 126, 38-44.
22. Dyson, S. J. (1995). Proximal suspensory desmitis in the hindlimb. Equine Veterinary Education, 7(5), 275-278.
23. Delius, M., et al. (1995). Biological effects of shock waves: in vivo effect of high energy pulses on rabbit bone. Ultrasound in medicine & biology, 21(9), 1219-1225.
24. Bosch, G., et al. (2009). The effect of focused extracorporeal shock wave therapy on collagen matrix and gene expression in normal tendons and ligaments. Equine veterinary journal, 41(4), 335-341.
25. Bischofberger, A. S., et al. (2006). Histomorphologic evaluation of extracorporeal shock wave therapy of the fourth metatarsal bone and the origin of the suspensory ligament in horses without lameness. American journal of veterinary research, 67(4), 577-582.
26. Maier, M., et al. (2000). Analgesic effect of low energy extracorporeal shock waves in tendinosis calcarea, epicondylitis humeri radialis and plantar fasciitis. Zeitschrift fur Orthopadie und ihre Grenzgebiete, 138(1), 34-38.
27. Wang, C. J., et al. (2012). Extracorporeal shockwave therapy shows time-dependent chondroprotective effects in osteoarthritis of the knee in rats. journal of surgical research, 178(1), 196-205
28. Frisbie, D. D., et al. (2009). Evaluation of the effect of extracorporeal shock wave treatment on experimentally induced osteoarthritis in middle carpal joints of horses. American journal of veterinary research, 70(4), 449-454.
29. Kawcak, C. E., et al. (2011). Effects of extracorporeal shock wave therapy and polysulfated glycosaminoglycan treatment on subchondral bone, serum biomarkers, and synovial fluid biomarkers in horses with induced osteoarthritis. American journal of veterinary research, 72(6), 772-779.
30. Dahlberg, J. A., et al. (2006). Force platform evaluation of lameness severity following extracorporeal shock wave therapy in horses with unilateral forelimb lameness. Journal of the American Veterinary Medical Association, 229(1), 100-103.
31. MacKay, A. (2019). A NOVEL APPROACH TO THE TREATMENT OF CAUDAL HEEL PAIN USING EXTRACORPOREAL SHOCK WAVE THERAPY (Doctoral dissertation, University of Saskatchewan).
32. Bar, K., et al. (2001) Extracorporeal shockwave therapy- a remedial procedure for navicular disease. Tierarzti. Prax. 29 (G), 1-5.
33. McClure, S.R., et al. (2004a) Extracorporeal shock wave therapy for treatment of navicular syndrome. In: Proc. 50th Ann. Convention of the Amer. Ass. of Equine Practitioners, Denver, Colorado, Dec. 4-8, p. 316-319.
34. Jeon, et al. (2012). The effect of extracorporeal shock wave therapy on myofascial pain syndrome. Annals of rehabilitation medicine, 36(5), 665-674.


FOR VETERINARY

Section 3 - Suggested treatment guidelines for Piezowave[2]

General considerations

- Guidelines and positions are merely suggestions for optimal results, each clinician may have different preferences for specific cases.
- Information is based on the clinical experiences of contributing clinicians. Clinicians utilizing the PiezoWave[2] report a wide range of guidelines as being effective and other published sources may vary from what is offered here.
- Gel pad size is selected based on the depth of tissue to be treated.
- It is important that the proper therapy source is used and that the end user understands the focal zone, distal and central penetration depth, and specific EFD for said therapy source.
- It is recommended to start low with both EFD and number of pulses and adjust according to patient's biofeedback.
- It is best to monitor the patient's response prior to increasing energy intensity.
- If a response is not seen after several treatments it is recommended to gradually increase the energy intensity.
- A treatment schedule of once every 7-14 days for 3-6 treatments is usually recommended.
- Treatment with shockwave should be part of a case specific program determined and monitored by a specialist in the veterinary field and is best paired with a rehabilitation program.
- Anatomical knowledge is needed for optimal therapy especially when treating specific distal limb structures.

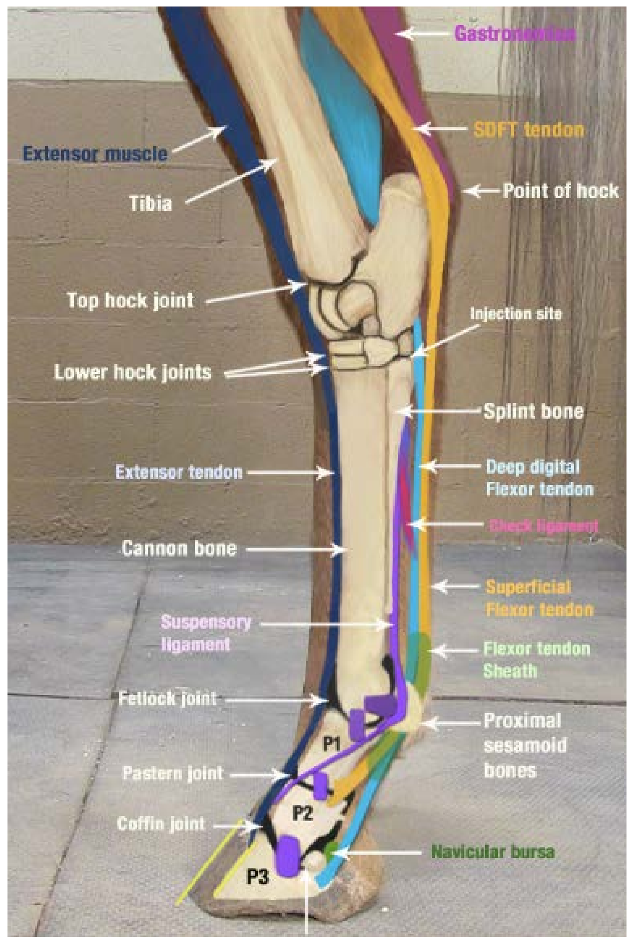


Figure 27 - Important soft tissue and boney structures in the equine hind distal limb.

Equine Musculoskeletal Anatomy

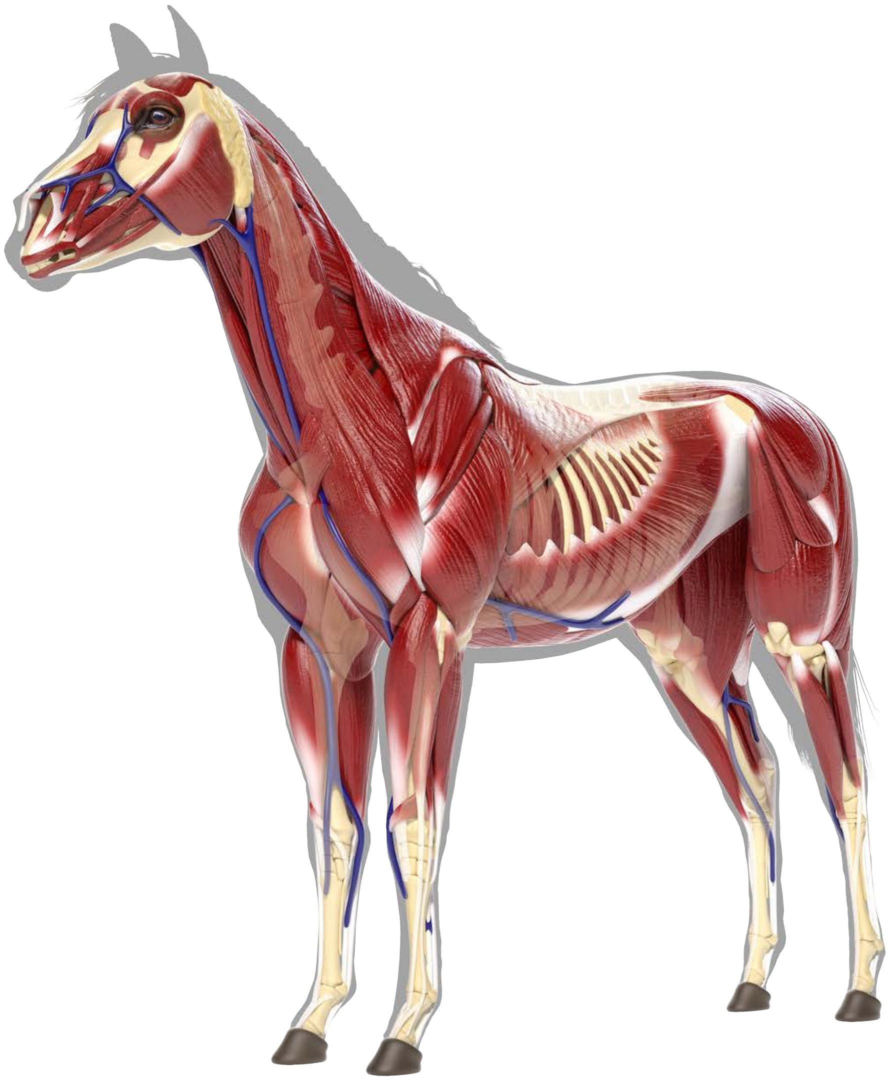
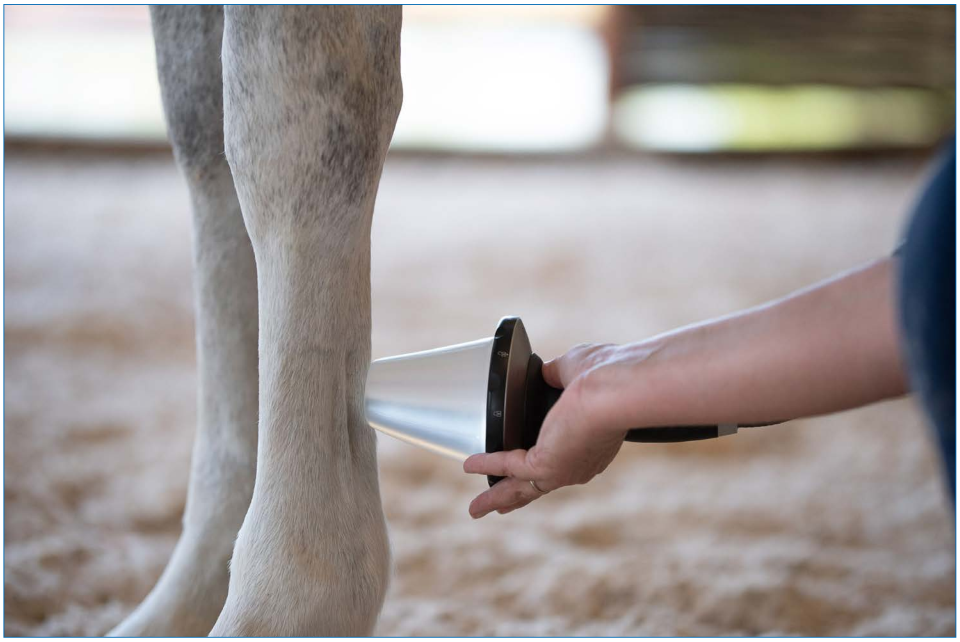


Figure 28 - Treatment of the equine axial skeleton with PiezoWave² can target muscle, fascia, tendon/ligament or boney structures.

Superficial digital flexor tendon- SDFT



Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm²	Intensity (dependent on therapy source)
5-30	8-12	2000	0.068-0.160	

The SDFT attaches to the superficial digital flexor muscle on the caudal aspect of the carpus. It runs through the carpal canal and down the palmar aspect of the cannon bone. The distal portion of the SDFT wraps around the deep flexor tendon at the level of the sesamoid bones and splits at the middle of the first phalanx. The distal SDFT attaches to the distal tubercles of the first phalanx and the adjacent fibrocartilage of the second phalanx. The SDFT functions to flex the pastern.

Position the therapy source on the injured tendon and move slowly along damaged tissue in the direction of the tendon fibers. Change angle and positioning to position damaged tissue within focal zone.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

Deep digital flexor tendon- DDFT

Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm^2	Intensity (dependent on therapy source)
5-30	8-12	2000	0.068-0.160	

The DDFT extends from the deep digital flexor muscle proximal to the carpus. It passes through the carpal canal and travels deep to the SDFT along the palmar cannon bone. At the middle of the cannon bone the strong accessory ligament (the check ligament) joins the DDFT. It travels palmar to the fetlock in the sleeve formed by the SDFT and continues down the palmar region of the first, second, and third phalanx. The distal portion of the DDFT wraps behind the navicular bone and inserts on the underside of the third phalanx. The DDFT functions to flex the distal limb.

Position the therapy source on the injured tendon and move slowly along damaged tissue in the direction of the tendon fibers. Change angle and positioning to position damaged tissue within focal zone.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

Suspensory ligament- body

Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm^2	Intensity (dependent on therapy source)
5-30	8-12	2000	0.068-0.160	

The suspensory ligament attaches to the caudal proximal aspect of the cannon bone with two separate lobes (medial and lateral). The body of the structure begins distal to the two proximal lobes. It travels just caudal to the splint bone and deep to the DDFT. The suspensory body ends at the bifurcation which is about two - thirds of the way down the cannon bone. The primary function of the suspensory ligament is to protect the fetlock from hyperextension.

Position the therapy source on the injured area of the suspensory body and move slowly along damaged tissue in direction of the ligament fibers. It is easiest to treat from either or both the medial and lateral sides of the suspensory body. Change angle and positioning to position damaged tissue within focal zone.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

Suspensory ligament- branch

Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm^2	Intensity (dependent on therapy source)
5-30	8-12	2000	0.068-0.160	

The suspensory branches begin at the bifurcation of the suspensory ligament, splitting into medial and lateral branches that attach to the abaxial portion of the respective proximal sesamoid bone. Suspensory branches function to stabilize the fetlock joint.

Position the therapy source on the injured suspensory branch and move slowly along damaged tissue in the direction of the tendon fibers. Change angle and positioning to position damaged tissue within focal zone.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO), stimulate neovascularization and bone remodeling if damage at the boney attachment

Proximal suspensory- front

Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm^2	Intensity (dependent on therapy source)
30-40	8-12	3000	0.144-0.323	

The front proximal suspensory has both a lateral and medial lobe that attach to the caudal proximal edge of the cannon bone just distal to the carpus. It is located deep to the digital flexor tendon and splint bones making it difficult to palpate. Injuries to the proximal suspensory often involve the bone-ligament interface.

Position the therapy source beneath the distal edge of the carpus where the suspensory ligament attaches to the cannon bone. The ligament bone interface is most easily accessed when the front limb is flexed and the flexor tendons are moved aside with light pressure from the therapy source. Move the therapy source slowly along damaged tissue in the direction of the ligament fibers.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO), stimulate neovascularization and bone remodeling

Proximal suspensory- hind

Standoff Pad (mm)	Frequency	Number of Pulses	EFD mJ/mm^2	Intensity (dependent on therapy source)
30-40	8-12	3000	0.144-0.323	

The hind proximal suspensory has both a lateral and medial lobe that attach to the caudal proximal edge of the cannon bone just distal to the hock. It is located deep to the digital flexor tendons and splint bones making it difficult to palpate. Injuries to the proximal suspensory often involve the bone-ligament interface and involve both bone and ligament damage.

Position the therapy source beneath the base of the hock on the medial side just below the chestnut. Due to the boney architecture of the distal hock the hind proximal suspensory is best accessed from the medial side. The therapy source is placed at a slight proximal cranial angle allowing the energy to pass between the splint bone and deep digital flexor tendon. The goal is for the energy to reach the attachment of suspensory ligament near the caudal proximal edge of the cannon bone. Move the therapy source slowly along damaged tissue in the direction of the ligament fibers.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO), stimulate neovascularization and bone remodeling

Fetlock joint osteoarthritis

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm^2	Intensity (dependent on therapy source)
20-30	8-12	1000-1500	0.144-0.323	

The fetlock in the thoracic limb is located between the 3rd metacarpal bone, the front cannon bone, and the first phalanx, P1, the long bone of the pastern. The fetlock in the pelvic limb is located between the 3rd metatarsal bone, the hind cannon bone and the first phalanx, P1, the long bone of the pastern.

Position the therapy source on the joint line, between the distal cannon bone and proximal first phalanx, P1. Energy can be applied moving the therapy source slowly along the joint line or holding it stationary at one or multiple points. Treatment of a known pathology is recommended and the energy can be targeted to the joint capsule, the synovial fluid, or the subchondral bone.

Goals of therapy: decrease inflammation, decrease pain, increase range of motion, vasodilation via upregulation of nitrogen monoxide (NO), angiogenesis, exhibit chondroprotective effects, stimulate stem cell production, dissolution of calcified fibroblasts, stimulate lubricin production, stimulate bone production, activate osteoblasts

*per area, a joint will often be treated from two areas: lateral and medial

Hock joint osteoarthritis

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
20-30	8-12	1000-1500	0.144-0.323	

The equine hock is a complex structure of ten bones and four joints organized within three different joint sacs. The four joints include from proximal to distal; the tarsocrural joint, the proximal intertarsal, the distal intertarsal, and the tarso-metatarsal. The tarsocrual joint, also known as the tibio-crural, is located between the tibia and the trochlea of the talus.

Position the therapy source on the affected joint line. This is often between the tibia and the talus. Energy can be applied moving the therapy source slowly along the joint line or holding it stationary at one or multiple points. Treatment of a known pathology is recommended and the energy can be targeted to the joint capsule, the synovial fluid, or the subchondral bone.

Goals of therapy: decrease inflammation, decrease pain, increase range of motion, vasodilation via upregulation of nitrogen monoxide (NO), angiogenesis, exhibit chondroprotective effects, stimulate stem cell production, dissolution of calcified fibroblasts, stimulate lubricin production, stimulate bone production, activate osteoblasts

*per area, a joint will often be treated from two areas: lateral and medial

Stifle joint osteoarthritis

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
20-30	8-12	2000	0.144-0.323	

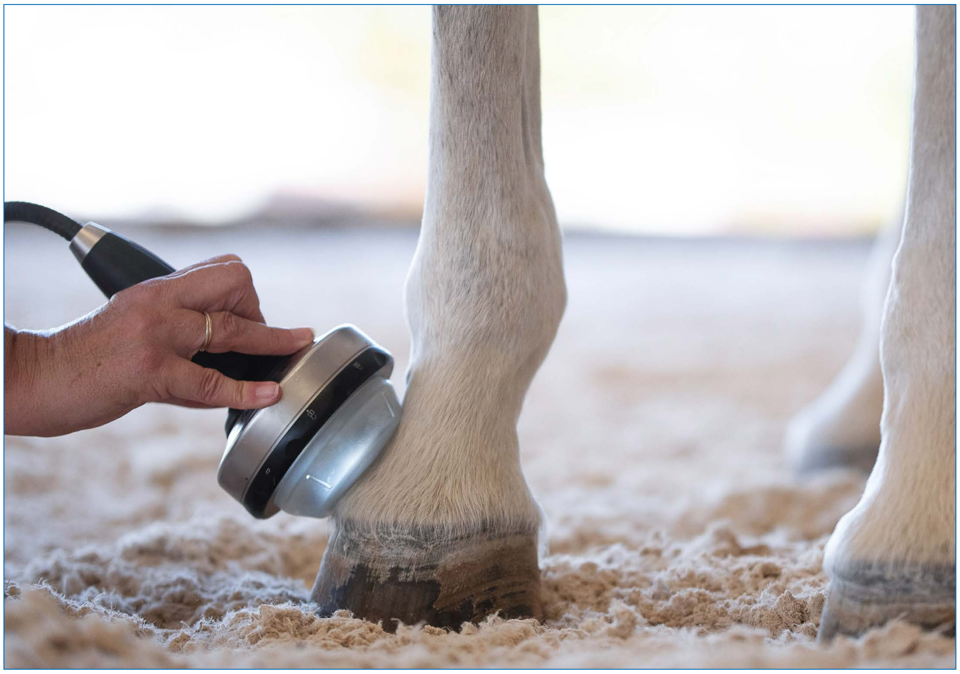
The stifle joint has two articular surfaces; the femoropatellar and femorotibial. The femorotibial joint is the weight bearing joint and has both a lateral and medial compartment that do not usually communicate. The joint is asymmetric with the medial femoral condyle larger than the lateral femoral condyle.

Position the therapy source along the the femorotibial joint line. If possible a slightly flexed joint will open the joint space. It is useful to treat from both the lateral and medial side. Energy can be applied moving the therapy source slowly along the joint line or holding it stationary at one or multiple points. Treatment of a known pathology is recommended and the energy can be targeted to the joint capsule, the synovial fluid, or the subchondral bone.

Goals of therapy: decrease inflammation, decrease pain, increase range of motion, vasodilation via upregulation of nitrogen monoxide (NO), angiogenesis, exhibit chondroprotective effects, stimulate stem cell production, dissolution of calcified fibroblasts, stimulate lubricin production, stimulate bone production, activate osteoblasts

*per area, a joint will often be treated from two areas: lateral and medial

Coffin joint osteoarthritis



Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm^2	Intensity (dependent on therapy source)
30-40	8-12	1000-1500	0.144-0.323	

The coffin joint is located between the coffin bone, 3rd phalanx, (P3) and the distal bone of the pastern, 2nd phalanx (P2). It is also called the distal interphalangeal joint.

Position the therapy source above the coronet band (1-2 cm above hoof wall) and angle the therapy source toward the opposite corner of the foot (30-45% angle from the front of the distal pastern). The energy is applied within the coffin joint and the distal interphalangeal joint. Energy can be applied moving the therapy source slowly along the joint line or holding it stationary at one or multiple points. Treatment of a known pathology is recommended and the energy can be targeted to the joint capsule, the synovial fluid, or the subchondral bone.

Goals of therapy: decrease inflammation, decrease pain, increase range of motion, vasodilation via upregulation of nitrogen monoxide (NO), angiogenesis, exhibit chondroprotective effects, stimulate stem cell production, dissolution of calcified fibroblasts, stimulate lubricin production

*per area, a joint will often be treated from two areas: lateral and medial

Caudal heel pain

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
20-30	8-12	3000	0.190-0.323	

Caudal heel pain can come from many different structures within the caudal heel including; the navicular bone, navicular bursa, collateral sesamoidean ligaments, the distal sesamoidian impar ligament, or the distal portion of the DDFT. Advanced imaging via an MRI is the gold standard for specific diagnosis within this area and can be used to help position focal zone of the energy on the appropriate structure.

Position the therapy source in the center of the heel bulb at the angle of the heel. The energy is generally focused on the navicular bone.

Goals of therapy: decrease inflammation, decrease pain, increase range of motion, vasodilation via upregulation of nitrogen monoxide (NO), angiogenesis, exhibit chondroprotective effects, stimulate stem cell production, dissolution of calcified fibroblasts, stimulate lubricin production, stimulate bone production, activate osteoblasts

*per area, navicular usually treated through one site on heel bulb. The energy is generally focused on navicular bone. Therapy source may be gently rocked to increase treatment area.

Cervical spine

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
20-80	8-12	1000	0.144-0.323	

The cervical spine has seven vertebrae that form a flexible long boney column that protects the spinal cord and both positions the head and balances the body.

If treating for facet joint pain from inflammation, synovitis, or OA, position the therapy source over the affected facet(s) between the transverse processes of the cervical vertebrae. Move it slowly in the distal direction with focal zone deep enough to reach the facet joint. Diagnostic ultrasound is recommended to identify affected areas. When treating in the area of C6-C7-T1 the therapy source is positioned just cranial to the shoulder and angled toward the center line of the sternum with a deep pad (60-80).

If treating myofascial pain in the neck area, the therapy source is slowly moved through the affected muscle groups in the direction of the muscle fibers.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

*per left and right side of each facet

Thoracic & lumbar spine

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
30-60	8-12	1000	0.144-0.323	

There are eighteen thoracic vertebrae including the withers. The have prominent dorsal spinous processes that decrease in size and change in angle from T1-T18. Each thoracic vertebrae is associated with an individual rib of the ribcage. There are six lumbar vertebrae that are located between T13 and the pelvis. The thoracic and lumbar vertebrae form a boney column to protect the spinal cord, provide core stability, and allow for mobility.

If treating for facet joint pain from inflammation, synovitis, or OA, position the therapy source lateral to the affected facet(s) and angle therapy source toward the spinal column. Diagnostic ultrasound is recommended to identify affected areas.

If treating myofascial pain in the thoracic or lumbar area, the therapy source is slowly moved through the affected muscle groups in the direction of the muscle fibers.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

*per left and right side of each facet

Sacroiliac area

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
60-100	8-12	1000	0.205-0.702	

The sacroiliac joint, the SI, is the connection between the sacrum and the illium. The sacrum is composed of five fused vertebrae and the tubersacral illium is the large fan shaped bone of the pelvis. It is a hinge joint that can be accessed with shockwave energy with similar positioning used for SI injections.

The SI is accessed from from both the cranial and caudal positions. Two cranial sites are on each side of the spine 4 - 5 cm off midline just cranial to the tubersacral illium with the therapy source angled about 45 degrees caudal so the energy reaches the cranial edge of the SI joint on both the left and right side. To treat the caudal aspect of the SI joint the therapy source is again placed 4- 5 cm off the midline but caudal to the tubersacral illium and angled straight down so the energy reaches the caudal edge of the SI joint on both the right and left sides.
If treating myofascial pain in sacral area or the sacral ligaments, the therapy source is slowly moved through the affected tissue in the direction of the tissue fibers.

Goals of therapy: decrease inflammation, promote stem cell activation, vasodilation via upregulation of nitrogen monoxide (NO)

* SI is often treated from four distinct sites

Splint bone

Standoff Pad (mm)	Frequency	Number of Pulses*	EFD mJ/mm²	Intensity (dependent on therapy source)
10-20	8-12	1500	0.111-0.168	

The medial splint bone (2nd metacarpal bone) and lateral splint bone (4th metacarpal bone) are positioned on either side of the proximal cannon bone (3rd metacarpal bone). There is a small interosseous ligament between the cannon bone and each splint bone that ossifies as the horse ages and the 3 bones become fused. Although splint bones do exist front and hind, the most common injury is to the medial front splint bone.

Position the therapy source along the splint bone at a 90 degree angle. Move slowly along the bone where the re-modeling is.

Goals of therapy: neovascularization, upregulation of vascular endothelial growth factor (VEGF) and endothelial nitric oxide synthase (eNOS), promote bone growth through cell proliferation and osteogenesis

*per area, a splint bone may be treated from multiple sites depending on size of boney changes

Section 3 References

Baljit, S. (2017). Dyce, Sack, and Wensing's textbook of veterinary anatomy. Dyce, Sack, and Wensing's textbook of veterinary anatomy., (Ed. 5).

Bischofberger, A. S., et al. (2006). Histomorphologic evaluation of extracorporeal shock wave therapy of the fourth metatarsal bone and the origin of the suspensory ligament in horses without lameness. American journal of veterinary research, 67(4), 577-582.

Bosch, G., et al. (2009). The effect of focused extracorporeal shock wave therapy on collagen matrix and gene expression in normal tendons and ligaments. Equine veterinary journal, 41(4), 335-341.

Chen, Y. J., et al. (2004). Extracorporeal shock waves promote healing of collagenaseβ induced Achilles tendinitis and increase TGFβ β 1 and IGFβ I expression. Journal of Orthopaedic Research, 22(4), 854-861.

Caminoto, E. H., et al. (2005). Ultrastructural and immunocytochemical evaluation of the effects of extracorporeal shock wave treatment in the hind limbs of horses with experimentally induced suspensory ligament desmitis. American journal of veterinary research, 66(5), 892-896.

Ciampa, A. R., et al. (2005). Nitric oxide mediates anti-inflammatory action of extracorporeal shock waves. FEBS letters, 579(30), 6839-6845.

Frisbie, D. D., Kawcak, C. E., & McIlwraith, C. W. (2004). Evaluation of extracorporeal shock wave therapy for osteoarthritis. Evaluation, 1438, 1204.

Giunta, K., et al. (2019). Prospective randomized comparison of platelet rich plasma to extracorporeal shockwave therapy for treatment of proximal suspensory pain in western performance horses. Research in veterinary science, 126, 38-44.

Kearney, C. J., Hsu, H. P., & Spector, M. (2012). The use of extracorporeal shock wave-stimulated periosteal cells for orthotopic bone generation. Tissue Engineering Part A, 18(13-14), 1500-1508.

McClure, S. R., et al. (2004). The effects of extracorporeal shock-wave therapy on the ultrasonographic and histologic appearance of collagenase-induced equine forelimb suspensory ligament desmitis. Ultrasound in medicine & biology, 30(4), 461-467.

Müller-Ehrenberg, H., & Licht, G. (2005). Diagnosis and therapy of myofascial pain syndrome with focused shock waves (ESWT). Med Orthop Tech, 5, 1-6.

Reinertson, E. L., & Hawkins, J. F. Extracorporeal Shock Wave Therapy for Treatment of Navicular Syndrome.

Trager, L. R., et al. (2020). Extracorporeal shockwave therapy raises mechanical nociceptive threshold in horses with thoracolumbar pain. Equine veterinary journal, 52(2), 250-257.

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