The use of shockwaves to crush uric concrements instead of removing them by surgical procedures has become a generally recognized tool in the hand of urologist in the 8th decade of the last century - less than thirty years ago! The effect to bony structures first has been recognized as an awkward side effect of this treatment and has become in at first timud use for the treatment of delayed fracture healing not even twenty years ago, but with the very quickly recognized side effect to reduce also the concomitant chronic pain.

In comparison to other physical methods and even to many surgical methods shockwave treatment in general is an extraordinarily young procedure. This fact always should be kept in mind expecting strong rules for well defined indications and a standardisation of the treatment in those indications with the assessment by the means of evidence based medicine. It was painful to learn that most of the clinical trials performed with the common scientific approach failed to prove the efficacy of shockwave treatment by statistic means without any doubt. The results of different clinical trials for the same indications have been very contradictory. But should this fact really take wonder? Up to now we don´t have been very contradictory. But should this fact really take wonder? Up to now we don’t have any chance in understanding the mechanism of ESWT effects to the living tissue in total. The application may be done by a doctor who is familiar with the indication as long as we are far away of understanding the mechanism of ESWT effects to the living tissue in total. The application may be done by medical personnel as well but also under supervision of a doctor who is familiar with the indications.

Nevertheless the experimental work has brought a fascinating progress in the last years by a change of mind on principle. In the last years of the last century the shockwave effect to the tissue was regarded as a kind of new trauma similar the demolition of the uric concrements, initiating somehow again the healing process. The interpretation of the results of different clinical trials for the same indications have been very contradictory. But should this fact really take wonder? Up to now we don’t have any chance in understanding the mechanism of ESWT effects to the living tissue in total. The application may be done by medical personnel as well but also under supervision of a doctor who is familiar with the indications.

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Treatment of osteonecrosis of the femoral head is stage dependent (1-4). For symptomatic hips, the principle is to preserve the femoral head in early cases (5). Conservative treatments are usually not successful, and core decompression with or without bone grafting is considered the gold standard (6-8). However, the results of core decompression are irregular and inconsistent, and many studies reported less satisfactory outcomes. Many patients eventually undergo total hip replacement (THR). The complications of THR in young active patients are high including thigh pain, polyethylene wear, mechanical loosening and infection (9).

Recently, extracorporeal shockwave therapy (ESWT) (10-13), hyperbaric oxygen therapy (HBO) (14,15) and oral alendronate (16-19) were reported to be effective in early ONFH. We have investigated the results of ESWT in young active patients. In a minimum of two years of follow-up, the results were improved in 74%, unimproved in 10% and worsened in 16% for ESWT group. At a minimum of five years of follow-up, the results were improved in 79%, unimproved in 10% for ESWT and 10% of ESWT plus alendronate (P = 0.717). THR was performed in 10% of group and 10.4% of ESWT group (P = 0.946). No discernable differences between the two groups were noted on X-rays and MR images. We concluded that ESWT is effective with or without the concomitant use of HBO and alendronate. The synergistic effects of HBO and alendronate over ESWT are not apparent in short-term.

Despite the good clinical results, the exact mechanism of ESWT remains unknown. Likewise, the working mechanism of ESWT in ONFH is poorly understood. To elucidate the working mechanism of ESWT, we have compared the ESWT-treated femoral heads with non-ESWT-treated ones prior to surgery using histomorphological examination and immunohistochemical analysis. The ESWT-treated femoral heads showed significantly more viable bone and less necrotic bone, higher cell concentration and more cell activities including phagocytosis than non-ESWT-treated specimens. In immunohistochemical analysis, the ESWT-treated femoral heads showed significant increases in VWF (von Willebrand factor) (P < 0.01), VEGF (vessel endothelial growth factor) (P = 0.0021), CD31 (PECAM-1 or platelet endothelial cell adhesion molecule-1) (P = 0.0023), Wnt3 (Wnt 3a) (P = 0.008) and P-CN (proliferating cell nuclear antigen) (P = 0.011), and decreases in VCAM (vascular cell adhesion molecule) (P = 0.0013) and DKK1 (Dickkopf-1) (P = 0.0007) than non-ESWT-treated hips (Fig. 1). It appears that ESWT significantly promotes angiogenesis and osteogenesis with bone regeneration in ONFH of the hip (Rheumatology in press). In conclusion, ESWT showed superior results than core decompression and non-surgical treatments such as HBO and alendronate in early ONFH. It appears that ESWT triggers the biological changes of angiogenesis and osteogenesis at the molecular level and results in tissue regeneration in hips with early ONFH.

References


NEW: Vibration therapy and Its Correlation with Application Time

When is the right time for ESWT?

Influence of ESWT on Ischemia Induced Tissue Necrosis and Its Correlation with Application Time

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Delayed/Non-healing or chronic wounds are an enormous challenge (physically, but also mentally) to each patient affected. Such wounds significantly impair the quality of life for millions of people. Intensive treatment is required and imparts an enormous burden on society in terms of lost productivity and health care costs.

Tissue ischemia/hypoxia is one of the major factors affecting an uncomplicated wound healing process potentially resulting in a chronic wound condition. Numerous surgical specialties are confronted with compromised tissue perfusion, often resulting in extensive operative revisions. This is especially seen in patients with co-morbidities such as diabetes and peripheral ischemic diseases (e.g. arteriosclerosis). The intrinsic capacity for physiological tissue regeneration is often severely impaired in these patients. If wounds require skin flap coverage in this patient population, then the transferred flaps may also be negatively affected by the underlying pathology. Skin flap surgery using autologous donor tissue is the treatment of choice for patients with large wounds or tissue defects. Depending on the size of the defect, either skin grafts, muscular flaps or composite flaps may be used. Necrosis of skin flaps, either partial or complete, remains a serious complication in skin flap surgery. Insufficient arterial (in)flow with the accompanying decreased nutritional supply to hypoxic/ischemic tissues can be potentially overcome by therapeutic angiogenesis. Numerous angiogenic factors have been studied for efficacy, for which an invasive approach with concomitant application of exogenous substances is common. The mode of administration for angiogenic factors has also been studied, as the intended clinical use and efficacy are a concern when known adverse effects occur with systemic administration.

Application of shockwaves in different medical indications has continuously expanded since its introduction in urology for encroachment disintegration. Since then, technique as well as application mode have been steadily modified and improved. Recently, extracorporeal shockwaves are being successfully used for treating chronic or delayed/disturbed healing wounds. Distinct advantages over other clinical and also experimental therapeutic approaches are the non-invasiveness and the avoidance of “exogenous medication” via various substances (e.g. growth factors, vasodilators). Although the mechanism of ESWT in ischemic soft tissue pathologies are still uncertain, it seems that shockwaves affect a complex spectrum of cellular and bio-molecular functions.

ESWT in experimental flap surgery

Effectiveness of ESWT in reducing ischemia-induced tissue necrosis was already shown experimentally in a rodent epigastric flap model (Figure 1). After rendering a certain part of the flap ischemic (ligation and dissecting a vascular bundle), shockwaves were immediately applied to the ischemic challenged tissue. Seven days after, the area of necrosis was substantially reduced in comparison to the untreated control group. Although this finding is of enormous clinical interest, clinicians (especially reconstructive surgeons) are regularly confronted with delayed (e.g. 24 hours) tissue necrosis following reconstructive (flap) surgery. Thus, a treatment option to intervene in such cases with already macroscopically visible failure is highly desirable. Such findings thus requirement as seen in delayed treatment of the above mentioned rodent epigastric flap performed in our institution. The study follow up showed that the ischemic challenged flap developed significantly less necrosis as compared with the control group (Figure 2).

A physiological process during wound healing is the wound contraction and reflects in some manner the quality of wound healing (collagen composition). Wound contraction should be minimal, especially for wound areas adjacent to joints which have to be covered by skin transplants or flap transfer. Preventing or minimizing contraction (extensive scar formation) results in less constrained range of motion in the involved joints and avoids surgical revisions. But also areas adjacent to orifices (face, beside the aesthetic point of view) are vulnerable to contraction and should be kept at a minimum. In the same study set up, less flap contraction concomitant with less necrotic area was observed. Encouraged by these findings, we addressed a further issue in elective treatment. Although in elective surgery a broad spectrum of possible complications can effectively be avoided, a residual risk which is inculcable exists especially in patients with co-morbidities (e.g. disturbed wound healing in diabetic patients). A tremendous amount of professional care efforts (wound care, wound revision) and social financial burden could be avoided if an elective treatment existed which would prepare the tissue as needed for the anticipated surgical intervention. Surgical procedures in a two stage manner were evaluated to reduce necrosis and showed effectiveness. For instance, in the first stage of flap surgery, only incisions will be made to induce the following increased tissue perfusion and to prepare the tissue for transfer in the second stage. Although this procedure shows a positive impact in the latter flap outcome, it nevertheless represents an invasive approach with its side effects (e.g. infection risk). When we experimentally applied shockwaves to the flap prior to surgery, we were able to see a reduction in necrotic area equal to the above mentioned delayed treatment. This is of great clinical relevance, because clinicians would have the opportunity to selectively treat patients prior to intended surgery who are at high risk of suffering from wound healing disturbances afterwards.

These findings in reducing tissue necrosis by ESWT are comparable with those studies which used exogenous growth factors (e.g. therapeutic angiogenesis) in the same indication.1,3,4 An enormous advantage, however, over these studies is the non-invasiveness of our approach in the application of shockwaves. Additionally, no adverse effects over the entire study period were observed. Further advantages are that the application is simple, it is well-received by the patients, and is cost effective.

Compromised tissue perfusion and the influence of ESWT

Probably one of the worst scenarios in reconstructive surgery (e.g. after free flap transfer with micro-anastomosis) represent tissue loss due to hypoxia or ischemia, as already mentioned above. Several apparatuses and methods exist for early detection of this unfavorable condition. However, treatment options after verification of this status are scarce. In the described animal model, flap ischemia could be verified beyond doubt by clear blue demarcation 24 hours after vessel ligation. In addition, a clinically used, non-contact, Doppler based system could confirm the clinical macroscopic finding. The principle is that a low intensity laser light beam scans the surface of the skin and generates a 2-dimensional image of flap perfusion. With this technology the ischemic impact was confirmed in all test animals by a distinct reduction in flap perfusion.

Recent studies, predominantly experimental ones, demonstrated that ESWT treated tissues, which were vulnerable to disturbed wound healing, showed modified release kinetics of essential growth factors LIT and induced angiogenesis. This improved circulation may have distinct benefits in wounds subjected to healing disturbances. Growth factors which are of interest included among others angiogenesis related factors and their early expression patterns. It was shown that these growth factors were up-regulated. This results in angiogenesis with concomitant improved tissue perfusion, increased cell proliferation and accelerated tissue regeneration.

"Competence in Shock Wave"
and healing.1,2,3 Using the Doppler based perfusion imaging system, a clear enhancement of circulation in the experimental flaps was noticeable at the time point when shockwaves were applied (Figure 3). This supports the hypothesis that angiogenesis with concomitant improved tissue perfusion/improved blood supply is one of the mechanisms of ESWT in ischemic/hypoxic wounds.

Transplant surgery is often confronted with limited healing of transferred tissue to the wound bed. Possible causes are seroma formation which prevents the nutritional supply from the wound bed to the overlying tissue, ultimately resulting in flap loss. Additionally, the lack of full tissue contact prevents the formation of new vessels (angiogenesis) which are mandatory for flap outcome, especially when subjected to a certain degree of hypoxia (ischemia). Macroscopic evaluation in our experiments showed that transplanted flaps treated with shockwaves have better adherence to the wound bed in the ischemic challenged flap area in comparison to controls which were left untreated. Surprisingly, this was not due to reduced seroma formation (nearly equal amounts between shockwave groups and control group).

In summary ESWT was found as a feasible therapeutic tool in preventing necrosis in ischemic challenged tissue. This therapeutic effect was seen as time-independent. This is of great clinical relevance, because the clinicians have a certain therapeutic window in which ESWT shows its effectiveness. Tissue subject to hypoxia/ischemia after surgery is eligible for this non-invasive, cost-effective approach and may help reduce extensive surgical revisions and prolonged wound care. Likewise, patients susceptible to wound healing disturbances could be treated prior to necessary surgical interventions, thus minimizing postoperative complications.

References

Figures:

Figure 1: Application of shockwave to the ischemic third of the flap using ultrasound guidance. (Blue line) is an epigastric flap with dimensions of approximately 6 x 8 cm, divided into vital, transition and ischemic areas. (Blue line).

Figure 2: Necrosis of entire flap on day 7 after surgery. Representative images of each group are depicted. A clear reduction of tissue necrosis is noticeable in all shockwave treatment groups in comparison to the control group. Within the different treatment groups no differences were found. (A) Control group (B) 24h post-OP group (C) 48h post-OP group.

Figure 3: Superficial flap perfusion assessed by LDV system. Depicted are typical perfusion images in the control group and post-OP groups during the 7 day interval. An increase in perfusion on day 7 postoperatively is evident in the flaps which were treated with shockwaves. Each group had a drop in perfusion post surgery caused by ligation of the neurovascular bundle (1h post ischemia).

Mid-portion Achilles tendinopathy - What role is there for shock wave treatment?

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Introduction

The incidence of midsubstance Achilles tendinopathy has risen. The condition is common in recreational and competitive athletes, particularly amongst runners and athletes participating in racquet sports, track and field, volleyball and soccer. The incidence of Achilles tendinopathy in top level runners has been estimated at between 7 and 9%. Of note, a 10-fold increase in Achilles tendon injuries has been reported in runners compared to age matched controls. However, Achilles tendinopathy is also common in the sedentary population. In a recent study, 31% of 58 Achilles tendinopathy patients did not participate in vigorous physical activity.

Aetiology and pathophysiology

Tendon injuries can be acute or chronic, and are caused by either intrinsic or extrinsic factors. In acute trauma, extrinsic loads exceed the tensile strength of the tendon. Overuse injuries generally have a multifactorial origin. Chronic studies in dysfuction, advanced age, body weight, pes cavus, and lateral ankle instability are common extrinsic risk factors. Changes in training pattern, poor technique, previous lower extremity injuries, footwear and environmental factors such as training on hard, slippery or slanting surfaces are extrinsic factors which may also predispose the athlete to Achilles tendinopathy.

The relationship between excessive tendon loading, clinical symptoms, and abnormal histopathology remains unclear. Excessive loading of tendons during vigorous physical training is generally regarded as the main pathological stimulus for degeneration but not all data supports this hypothesis. In one study on chronic Achilles tendinopathy (342 tendons), physical activity was not correlated to the extent of histopathological change, suggesting that physical activity may be more important in evoking the symptoms then being the root cause of pathology. The lack of association between activity, pain and structural abnormality has also been reported in other pathology. Further pathological changes are seen not uncommonly seen on imaging studies in asymptomatic individuals who are physically active.

Tendons respond to repetitive overload beyond physiological threshold by either inflammation of their sheath, degeneration of their body, or a combination of both. It remains unclear whether different stresses induce different responses. Tendon damage may also occur from

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Evidence of prostaglandin-mediated quantitative PCR) of appropriately intratendinous microdialysis and characterized by cellular activation and structure.40 In general, tendinopathy is intratendinous accumulation of lipid patches and vacuoles between fibres. Tendon ‘mucoid’ or ‘lipoid’ degeneration is after histopathological examination. Tendons arising from overuse, and the clinical conditions in and around tendinopathic Achilles tendon samples.

Histopathology
The pathological label ‘tendinosis’ is used to describe the disorganized impaired healing response in tendinopathic Achilles tendons. Most clinicians still use the term ‘tendinitis’ or ‘tendinosis’, thus implying that the fundamental problem is inflammatory. Achilles tendinopathy as a generic descriptor of the clinical conditions in and around tendons arising from repetitive microtrauma. It is suggested that the term tendinosis, tendinits and tendinitis only be used after histopathological examination. Various types of degeneration may be seen in tendons, but in the Achilles tendon ‘mucoid’ or ‘lipoid’ degeneration is usually seen. In mucoid degeneration, night microscopy reveals large mucous patches and vacuoles between fibres. In lipid degeneration, abnormal intratendinous lipidinclusions occur, with loss of collagen fibre structure 40. In general, tendinopathy is characterized by cellular activation and treatment becomes more complicated and less predictable when the condition becomes chronic: 

Imaging methods
Achilles tendinopathy is a clinical diagnosis mainly based on a careful history and detailed clinical examination. At times, however, however, diagnostic imaging may be required to verify a clinical suspicion or, occasionally, to exclude other musculoskeletal disorders. Ultrasonography is widely used in European countries. It is easily available, quick, safe, and inexpensive. However, ultrasound is operator-dependent, and there is not as sensitive as MRI. The current evidence for most of conservative and outcome.

Clinical Presentation
Pain is the cardinal symptom of Achilles tendinopathy. Pain is often local, beginning at the start and resolving after the end of the exercise session, with a period of diminished discomfort in between. As the pathological process progresses, pain may occur during the entire exercise session, and, in severe cases, it may interfere with activities of daily living.

In the acute phase, the tendon is diffusely swollen and edematous, and palpation tenderness is usually greatest 2 to 3 cm proximal to the tendon insertion. Crepitation is common. In chronic cases, exercise-induced pain is still the cardinal symptom, but crepitation and edema develop. Common signs are the tendon becomes thick, firm, and nodular.

The first priority of the clinical examination is to examine for new-onset rupture. The call sign test is easy to perform and has excellent validity. After demonstrating that the tendon is intact, the stress test helps to confirm a possible rupture during tendon-loading activity. In most patients, simple single-leg heel raises will be sufficient to cause pain. In more active individuals, however, it may be necessary to ask the patient to hop on the spot, or hop forward, to confirm the diagnosis of rupture.

The differential diagnoses include tenosynovitis or dislocation of the peroneal or other plantar flexor tendons, impingement or neuritis of the sural and tibial nerve, and systemic inflammatory disease. Although these conditions may cause pain in and around also the Achilles tendon, they are nearly always confined to the tendon itself.

Eccentric training is a popular treatment for Achilles tendinopathy. The eccentric exercise program. The eccentric exercise program is designed to overload the tendon, but vessels remained in the two non-tendinopathic Achilles tendinopathy. Peritendinous injections with corticosteroids or local anaesthesia have been discussed. In one observational study, patients satisfied with the result of the eccentric training regimen had no remaining neovascularisation, and all patients with a poor clinical result continued to demonstrate neovascularisation. This hypothesis was not supported by recent publications.

Due to its promising results, eccentric training has been evaluated in several randomised controlled trials in the Achilles tendon. Eccentric training is an exercise that decreases the pain score and improves function in patients with Achilles tendinopathy. In a recent randomised, controlled trial, Vaskonen et al. reported that eccentric training was associated with a significant reduction in pain and improved function in patients with Achilles tendinopathy. In a recent randomised, controlled trial, Vaskonen et al. reported that eccentric training was associated with a significant reduction in pain and improved function in patients with Achilles tendinopathy.
None of several possible explanations for the clinical effectiveness of shock wave treatment have been fully investigated. The rationale for SWT in clinical use is in inhibition of pain receptors and stimulation of soft-tissue healing. In the periphery, SWT leads to a secondary dysfunction of sensory unmyelinated nerve fibres without affecting the large myelinated nerve fibres responsible for motor function. For high energy treatment, this selective destruction of sensory unmyelinated nerve fibres within the focal zone of SWT may contribute to clinically evident long-term analgesia. For low-energy application, analgesia may result from shock wave-induced destruction of sensory nerve fibres with liberation of neuropeptides, such as calcitonin gene related peptide (CGRP), resulting in a local neurogenic inflammation in the focal area with subsequent prevention of sensory nerve endings from re-innervating this area. Clinically, the reduction in the number of neurons immunoreactive for CGRP and substance P without a reduction in the total number of neurons within the lower lumbar dorsal root ganglia (DRG) probably is a secondary effect following the decrease in the number of sensory nerve fibres in the focal zone of shock wave application. Similar results were reported for neurons immunoreactive for CGRP within the DRG of the rat following therapeutic ultrasound. In the only human experiment, Koenschinski investigated whether the biological effects of SWT differed between application with and without LA. SWT was applied to the skin either after local pre-treatment with lidocain LA. Low-energy SWT (LSWT) produced a statistically higher number of neo-angiogenesis and angio genesis- related markers, including endothelial patic axis, microtubule and nucleolus endothelial growth factor and proliferating cell nuclear antigen than the control without SWT. Only an optimal number of 100-200 impulses of LSWT promoted clinical resolution of Achilles tendinopathy by inducing TGF-beta, and IGF-I and increased the contact between bone and tendon as well as tendinocyte strength.

**Conclusions**

Although Achilles tendinopathy has been extensively studied, there is a clear lack of properly conducted scientific research to clarify its etiology, pathology and management. Most groups report to conservative measures if the condition is recognised early, while continuing the offending activities leads to chronic changes which are more resistant to non-operative management. Teaching patients to control the symptomatic phase may be more beneficial than limiting them to believe that Achilles tendinopathy is fully curable. In randomised controlled studies, painful eccentric heavy loading exercises and shock wave treatment have shown encouraging outcomes. Surgery usually involves removal of adhesions and degenerated areas, and longitudinal tenotomy may influence the local circulation in a beneficial way. It is still debatable why tendinopathic tendons respond to surgery. For example, we do not know whether surgery induces revascularisation, denervation or both, resulting in pain reduction. It is unclear how longitudinal tenotomy improves vascularisation. As the biology of tendinopathy is poorly understood, more effective management regimens may come to light, improving the success rate of both conservative and operative management.

**Introduction**

Previously the Extracorporeal Shock Wave Therapy (ESWT) was established for example for diminishing renal calculi and gallstones. Currently the ESWT is successfully used in therapy against pseudarthrosis, plantar fascitis, tendinosis calcarea and wound healing disorders. Numerous in vivo studies underline the good results of this method of therapy. Our studies are focused on cellular effects of extracorporeal shock waves on migration, proliferation and growth of isolated human mesenchymal stem cells (MSCs). MSCs have been discussed for a very long time as being a useful tool for the treatment of various disfunctions. For therapeutic application of MSCs different invasive methods have been described. Stem cells are generated extracorporeal and would represent a first non-invasive way to influence and guide MSCs to the target area.
Mechanotransduction

The Mechano Transduction leads to the transformation of mechanical sensations into cellular impulses. The routes of these impulses are time-dependent in different supporting connective tissue. These routes induce a certain flow direction of information. Thereafter arising follow-up signals, which are considered as biological information units, lead to very specific signals and thus to equally specific biological transformation within the cellular structure.

The adherence to precise method of application by means of mechanical stimulus is of utmost importance. For the first time we were able to prove that mechanical activation of stem cells is possible with the help of extra corporal shock waves. Hereby establishing further therapy methods.

Adult Stem Cells

Within the grown-up body stem cells are found during the whole life. These so-called adult stem cells mainly occur in the bone marrow, but also in the liver and brain. Until today it is not exactly clear as to whether they might exist in other organs as well. As opposed to embryonic stem cells which can diversify into all types of tissue, adult or specific stem cells exhibit a limited potential for differentiation.

Embryonic Stem Cells

Stem cells first appear during the early embryonic development. The fertilized ovum (Zygote) already represents a totipotent stem cell, which is able to develop all kinds of human tissue.

Mesenchymal Stem Cells (MSCs)

The MSCs are omnipotent, they are able to differentiate not only in vivo but also ex vivo in special tissue cells: heart and skeleton muscle cells, bone and cartilage cells, connective and fat tissue.

Ways of Differentiation ofMSCs

The purpose of the MSCs is the regeneration and repairation of tissue.

This means:

Stem cells are necessary for the repairation and regeneration within living tissue.

Furthermore:

Aging is a process of imbalance between degeneration and regeneration.

Putting it differently:

The loss of self-renewal in adult stem cells describes one of the most important reasons for growing old.

The question of the following study was:

Are extracorporal shock waves able to influence the activity, proliferation and growth of MSCs?

The study was approved by the local ethics committee and conforms to the declaration of Helsinki.

Some pictures are to find by internet http://stemcells.nih.gov/info

Materials and Methods

Application of Shock Waves

Shock waves were applied to adherent MSCs. In order to imitate natural application in in vivo culture dishes were completely filled with media and covered with freshly prepared pork skin.

Ultrasound gel was placed on top of the pork skin to ensure best adjustment to the shock wave system.
Results

1. Boyden Chamber Assay

Migration Assay was performed in a modified Boyden-Chamber assay. 5 x 10⁴ single cells were put onto the top of a Falcon® HTS Flouro Black™ inserted and incubated for 8 hours in 20 % alpha-MEM.

For the shock wave treatment 3 parameters were altered:
- Number of applications (500 or 1000 applications)
- Frequency (2 or 4 applications per second)
- Density of energy (from 0.048 mJ/mm² to 0.238 mJ/mm²)

2. Growth rate

Growth of MSCs significantly increased in the first passage after the shock wave treatment. In later passages MSC growth was not influenced compared to the control reference.

3. Proliferation Assay with Anti-Ki67

Shock waves significantly increase the proliferation of MSCs.

Summary and Conclusions

- Shock waves increase the migratory activity of MSCs when using distinct conditions.
- The results of shock wave treatment depend on number of applications, frequency and density of energy.
- Shock waves increase MSC growth in the first passage after treatment.
- Shock waves significantly increase MSC proliferation.
- Shock waves might be the first approach to mobilise stem cells without invasion.
- The strong effects of shock waves onto MSCs indicate that these cells can be influenced by mechanical stimuli.

Summary

Calf muscle tightness and restricted dorsiflexion of the ankle joint are risk factors for many lower limb disorders, especially Achilles tendinosis. The origin of the muscle tightness remains unclear, but reducing the tension within the musculo-tendinous system leads generally to a reduction of pain.

The aim of this retrospective study was to investigate the possibility of improving active calf muscle extensibility by the use of Extracorporeal Pulse Activation Therapy (EPAT) in patients with chronic Achilles tendon pain and restricted dorsiflexion in the ankle joint. Therefore, pressure pulse waves were applied to the shortened calf muscles in 78 patients, and active dorsiflexion of the affected ankle joint was measured before and after therapy. The mean active dorsiflexion measured prior to Extracorporeal Pulse Activation Therapy was 2.6° (SD 3.7°; range -3° to 10°). After an average of 4.6 sessions with 6000 pressure waves per session, a significant increase in active dorsiflexion to 11.5° (SD 5.1°; range 2° to 21°) was found. Follow-up examinations conducted after an average of 4.2 months (range 3 to 6 months) after the end of therapy showed a persistent increase in maximal active dorsiflexion to 11.7° (SD 5.6°; range 2° to 22°). As the pain in the treated muscle indurations decreased, pulse intensity could be increased from 1.8 bar to 3.4 bar during therapy.

The mode of action of acoustic pulse waves in muscles is in accordance with the trigger point theory, but needs to be investigated in more detail by experimental studies.

One of the most effective therapies in use is the application of manually administered mechanical pressure on the trigger points. This is generally done by using the friction massage technique, followed by muscle stretching. Examinations into the effectiveness of classical trigger point therapy in improving active calf muscle extensibility are not dealt within the cited literature. The effectiveness of calf muscle stretching alone is discussed controversially,

In the last few years, the use of low to medium energy Extracorporeal Pulse Activation Therapy (EPAT) has become increasingly established in the treatment of myofascial pain, especially in the German speaking European countries (Germany, Austria, and Switzerland). On the basis of the aforementioned pressure application theory in the treatment of trigger points, it is questionable whether acoustic pulse waves are able to provide an improvement in the extensibility of shortened calf muscles.

Material and Methods

Subjects

A retrospective study was conducted on 78 patients of an orthopaedic practice (56 men and 2 women), mean age 45.3 years (SD 11.2; range 23 to 58 years), with unilateral chronic (> 6 months) Achilles tendon pain (mean 21.2 months; range 6 to 137 months). 69 patients complained about an mid-portion tendon pain, 9 about an insertional pain. All patients were recreational athletes and had a history of failed conservative treatments for Achilles tendon pain with NSAIDs, local cortisone injections, and physiotherapy. Physiotherapy included stretching exercises but they were not executed regularly and were part of a specific stretching program. The inclusion criterion was a reduction in active ankle joint dorsiflexion equal or less than 10°, due to shortened calf muscles when examined at full hip and knee extension.

Key Words:

- EPAT, calf muscle shortening, stretching, muscle extensibility, Achilles tendinosis, trigger points.

Introduction

Active calf muscle shortening may be the presence of trigger points 8 in the calf muscles. The permanent contracture of the actin-myosin filaments caused by trigger points, due to the energy crisis of the motor end plate, leads to circumscribed muscle contractures which, in the presence of a sufficient number of trigger points, result in a measurable overall shortening of the affected muscles and in a limited dorsiflexion of the ankle joint. There are numerous causes for trigger point development, ranging from mechanical overstrain, trauma or poor posture to articular, neurogenic or remote muscular disorders (satellite trigger points). Rest and medications (NSAID) help in pain relief, but do not eliminate the underlying contracture, which persists for years and leads to recurrent injuries. With time the trigger pathology often increases, as the malfunction induces a permanent overload of neighboring muscle area.

One of the most effective therapies in use is the application of manually administered mechanical pressure on the trigger points. This is generally done by using the friction massage technique, followed by muscle stretching. Examinations into the effectiveness of classical trigger point therapy in improving active calf muscle extensibility are not dealt within the cited literature. The effectiveness of calf muscle stretching alone is discussed controversially, as this therapy approach is considered to induce only a temporary and little improvement in flexibility.

In the last few years, the use of low to medium energy Extracorporeal Pulse Activation Therapy (EPAT) has become increasingly established in the treatment of myofascial pain, especially in the German speaking European countries (Germany, Austria, and Switzerland). On the basis of the aforementioned pressure application theory in the treatment of trigger points, it is questionable whether acoustic pulse waves are able to provide an improvement in the extensibility of shortened calf muscles.
Derive for Extracorporeal Pulse Activation Therapy (EPAT)

Therapy was carried out with the D-Actor™ 100 system (Fig. 1) developed by Storz Medical AG for orthopedic pain therapy in humans. The machine produces acoustic pulses with an energy flux density (EFD) up to 0.23 mJ/mm² and a maximal pulse frequency of 15 Hz.

The mode of action is identical to that used by pneumatic jack-hammers: a ballistic source (air compressor) generates stress waves by means of a projectile impacting a solid applicator in the handpiece (Fig. 2). The face of the applicator (20 mm diameter) has to be covered with coupling gel and then firmly pressed perpendicularly on the patient’s skin. During each session, 6000 pressure wave pulses were applied to the calf muscles, with the patient lying in the prone position on the examination table (Fig. 4). Pressure waves were mainly administered locally to the proximal gastrocnemius and soleus muscles, where palpable indurations were found. The middle part of the soleus muscle was treated through the gastrocnemius muscles, whereas the distal muscle portion, often indurated as well, was freely accessible medial and lateral to the most proximal Achilles tendon.

The palpable muscle indurations were considered as areas of trigger points and were therefore in the focus of the therapy. These areas were always healing and painful during the pressure wave treatment than the rest of the calf muscles. They were treated locally with 500-1000 pulses each until the pain diminished. After choosing 4-6 trigger areas per session, the remaining 1000-2000 pulses were administered widely spread over the rest of the calf muscles (smoothing technique).

The maximum driving pressure as a measure for the EPAT pulse transmitter (D-Actor™) was adjusted to the patient’s pain threshold and was tried to be increased during therapy. The pulse repetition frequency was 15 Hz. The number of sessions was determined according to the effectiveness of the 4-2 sessions (range 3 to 6 months) to the end of the pressure wave therapy. Application of pressure waves was strictly avoided over vessels and nerves as this may lead to damage of the same orthopedic physician (MG), who has an experience of several thousand pressure wave and shock wave treatments.

Instrumentation and Measurement of Axial Joint Dorfisoxion

The active dorfisoxion of the ankle joint was measured by means of a Bio-Medical pressure goniometer** made of transparent plastic.

The examiner (MG) sat at the level of the ankle and held the goniometer against the patient’s foot sole without exerting any pressure. Patients lay prone on a standard treatment table, both hip and knee joints extended. This is the position in which the gastrocnemius is maximally stretched. The foot was hanging over the table’s edge, the ankle joint in neutral rotation. Before measurement patients were asked to actively dorsiflex and plantar flex through the available ROM 4 times for the testing of preconditioning the soft tissues, according to the procedure recommended by Zito et al.12 After the next maximum active dorfisoxion angle was taken as the measurement. Measurements were taken before treatment, 1 week after the last treatment and as a follow-up to 6 months later.

Statistical evaluation

The statistical evaluation was performed using the SPSS™ software (version 11.5.0). The results of ankle mobility are expressed as mean with standard deviation (SD) Differences in active ankle joint dorfisoxion before and after treatment were calculated with a non-parametric test: paired samples using the Wilcoxon signed rank test. A p-value less than 0.05 was considered significant.

Results

The mean active dorfisoxion measured prior to Extracorporeal Pulse Activation Therapy was 1.6° (SD 1.9° to 3.7°)**. After an average of 4 sessions (range 4 to 6 sessions) a significant increase (p=0.034) in active dorfisoxion to 11.5° (SD 5.1°; range -2° to 21°)** was found. Follow-up examinations confirmed the positive results: after 4-2 sessions (range 3 to 6 months) after the end of pressure wave therapy, a showed a significant increase (p=0.013) in the dorfisoxion to 11.7° (SD 5.6°; range -2° to 22°)**. No significant difference was identified between the results of the dorfisoxion angle was taken as the end of the therapy and at follow-up 4.2 months later (p = 0.96). During therapy the pressure wave intensity could be increased in all patients. The average intensity at the first session was 1.8 bar (range 1.6 to 2.6 bar) at the last session 3.4 bar (range 3.0 to 4.0 bar). Palpation after therapy showed a much softer muscle tissue and a disappearance of most indurations. Patients reported the feeling of more flexible calf muscles and an easier gait after treatment. Shock waves were considered to be subcutaneous hematomas during the first two sessions. Sonographic examinations excluded any degenerated lesion in the muscle mass** and in the muscles of the foot.** A plausible explanation for the effectiveness of EPAT might be given by the trigger point theory. The presence of trigger points in muscles causes a significant motor dysfunction with the clinical findings of a restriction of full stretching range of motion, a palpable increase in muscle tenerness and painful contraction knots. The histological findings in a contracture knot are segments of muscle fibers with extremely contracted sarcomeres and improvement in local collagen and improved local fluid exchange. This would mean that the treatment of a shortened Achilles tendon is, in the opinion of the author, misleading and is not fully consistent with the practical experience of this study. In fact, the increase in ankle dorsiflexion achieved by an exclusively local treatment of the painful contracture knots is less than expected. Therefore, the pain of gastrocnemius and soleus muscles remains far behind the improvement provided by the combined treatment of both muscles. The fact that trigger point areas described above (smoothing technique of the whole muscle) would mean that the effectiveness is far due to the painful active trigger points but also due to painless latent trigger point areas within the whole muscle, which also respond to EPAT.

Conclusion

The results of this practical study are encouraging, but need to be verified by means of methodically more valid studies and by conducting experimental examinations of the specific mode of action. Except for the pain perception, the therapy has no influence. EPAT has only minimal side effects and is indicated for almost all patients with calf muscle shortening.

The following reasons for the effectiveness of the historically accepted combination of deep friction massage and shock wave therapy for the treatment of trigger points are discussed:conclusion of actin- myosin contractile force and the elimination of trigger points only is, in the opinion of the author, misleading and is not fully consistent with the practical experience of this study. In fact, the increase in ankle dorsiflexion achieved by an exclusively local treatment of the painful contracture knots is less than expected. Therefore, the pain of gastrocnemius and soleus muscles remains far behind the improvement provided by the combined treatment of both muscles. The fact that trigger point areas described above (smoothing technique of the whole muscle) would mean that the effectiveness is far due to the painful active trigger points but also due to painless latent trigger point areas within the whole muscle, which also respond to EPAT.

References


### Table 1. Results: Active Ankle Joint Dorsiflexion before and after EPAT

<table>
<thead>
<tr>
<th>Treatment Group (n=78)</th>
<th>Ankle Dorsiflexion (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before therapy</td>
<td>3.6 ± 3.7</td>
</tr>
<tr>
<td>After therapy</td>
<td>11.5 ± 5.1</td>
</tr>
<tr>
<td>P</td>
<td>0.001^a</td>
</tr>
<tr>
<td>Follow-up</td>
<td>11.7 ± 5.6</td>
</tr>
<tr>
<td>P</td>
<td>0.001^b</td>
</tr>
</tbody>
</table>

^a Comparison between before and after therapy
^b Comparison between before therapy and at 4.2-month follow-up