Collection of studies regarding healing of fractured bones with low-intensity but high frequency pulsed ultrasound

This listing constitutes a selection of the current knowledge available and clinical experience made treating different types of patients with a series of low-intensity but high frequency pulsed ultrasound. The list is not a claim to completeness.

Table of contents

1999

1: Unfallchirurg. 1999 Mar;102(3):191-6.
Ultrasound therapy for nonunions. Three case reports
Mayr E, Wagner S, Ecker M, Ruter A.
Klinik für Unfall- und Wiederherstellungschirurgie, Zentralklinikum Augsburg.

Despite of the good results of operative treatment disorders of fracture healing are still a challenge for surgeons. In some cases all endeavours are frustrating and bone does not heal. Low intensity pulsed ultrasound (frequency: 1.5 MHz, pulsed by 1 KHz, signal burst width: 200 musec, intensity: 30 mW/cm2) offers the opportunity of an alternative treatment. In contrast to magnetic field therapy, electric stimulation or use of extracorporal shock waves this therapy is judged positively all over the literature. Within an own series of 76 cases at present time we can show a 86% healing rate under defined conditions. Within this paper we present three case reports, which clearly show the efficiency of low intensity pulsed ultrasound.

PMID: 10232035 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=10232035

2000

Handchir Mikrochir Plast Chir. 2000 Mar;32(2):115-22.
Does low intensity, pulsed ultrasound speed healing of scaphoid fractures?
Mayr E, Rudzki MM, Rudzki M, Borchardt B, Hausser H, Ruter A.
Klinik fur Unfall- und Wiederherstellungschirurgie, Zentralklinikum Augsburg.

Since pulsed low-intensity ultrasound (frequency: 1.5 MHz, pulsed by 1 kHz, signal burst width: 200 microseconds, intensity: 30 mW/cm2) has been proven to stimulate fracture healing both clinically and experimentally, our question was whether this therapy also accelerates healing of fresh stable scaphoid fractures. Addressing this question, we did the following prospective randomized clinical trial. Regarding the results of former clinical fresh fracture studies by Heckman and Kristiansen, we postulated that low intensity ultrasound accelerates healing by about 30%. Based on this thesis, we calculated that 30 patients divided into two groups would be necessary to show significant differences between the standard treatment (treated by casting) and an adjunctive ultrasound treatment (treated by casting and additional daily 20 minutes ultrasound treatment) if present. Diagnosis and healing was assessed by CT scans every two weeks. CT's were analyzed by two independent radiologists and one hand surgeon. Furthermore, areas of cancellous bone bridging in correlation to the diameter of the scaphoid was measured in each CT scan. The results showed ultrasounded fractures healing in 43.2 +/- 10.9 days versus 62 +/- 19.2 days in the control group ($p < 0.01$). Trabecular bridging six weeks after injury showed 81.2% +/- 10.4% healed in the ultrasound-stimulated fractures versus 54.6% +/- 29% in the control ($p < 0.05$). Our study results confirm those of Heckman and Kristiansen and show a similar acceleration of bone healing. Low intensity ultrasound is successful in accelerating the healing of fresh scaphoid fractures.

PMID: 10857066 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=10857066

1: Arch Orthop Trauma Surg. 2000;120(1-2):1-8.
Ultrasound--an alternative healing method for nonunions?
Mayr E, Frankel V, Ruter A.
Klinik fur Unfall- und Wiederherstellungschirurgie, Zentralklinikum Augsburg, Germany.

Several years ago, low-intensity pulsed ultrasound (frequency 1.5 MHz; signal burst width 200 micros; signal repetition frequency 1 KHz; intensity 30 mW/cm2) was shown to accelerate fresh fracture healing both clinically and experimentally. On the basis of a prescription use registry, this paper reports on the use of low-intensity pulsed ultrasound in the therapy of 951 delayed unions and 366 nonunions. The overall success rate for delayed unions was 91% (average healing time 129+/-2.7 days) and for nonunions 86% (average healing time 152+/-5.3 days). Stratifying the data, it becomes clear that patient medication with calcium channel blockers, non-steroidal anti-inflammatory drugs, and steroids is a negative predictor for healing nonunions, as well as renal or vascular insufficiency. Patients who were smokers during ultrasound therapy had lower healing rates than those who never smoked. When comparing the patients of our own clinic treated with low-intensity ultrasound under study conditions which demonstrate that if healing was achieved it was an effect of the ultrasound therapy to the worldwide prescription use registry, no difference was seen in healing rate, healing time, or fracture age. Therefore, the results of these two populations support each other. Low-intensity pulsed ultrasound may provide a method of nonoperative treatment of great promise for healing disorders. Determination of ranking of this new method should be done within the near future.

PMID: 10653095 [PubMed - indexed for MEDLINE]

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=10653095

2001

1: J Trauma. 2001 Oct;51(4):693-702; discussion 702-3.
Low-intensity pulsed ultrasound in the treatment of nonunions.
Nolte PA, van der Krans A, Patka P, Janssen IM, Ryaby JP, Albers GH.
Department of Orthopaedics, Academic Medical Center, University of Amsterdam, The Netherlands. panolte@knmg.nl

BACKGROUND: Low-intensity ultrasound has demonstrated an acceleration of bone healing and more profound callus formation in animal and human clinical experiments. In this study, the effect of pulsed, low-intensity ultrasound was determined in established nonunion cases. METHODS: The enrolled cases were reviewed for the time from their last surgical procedure and evidence of no healing or progression of healing during the 3 or more months before the start of low-intensity ultrasound therapy to determine whether the cases were established nonunions. Twenty-nine cases, located in the tibia, femur, radius/ulna, scaphoid, humerus, metatarsal, and clavicle, met the criteria for established nonunions. On average, the postfracture period before the start of ultrasound treatment was 61 weeks. Initial fracture treatment was conservative in 8 cases and operative in 21 cases. Additional treatments including bone grafting, reosteosynthesis, and other surgical procedures were performed an average of 52 weeks before the start of ultrasound treatment. Daily, 20-minute applications of low-intensity ultrasound at the site of the nonunion were performed by the patients at home. RESULTS: Twenty-five of the 29 nonunion cases (86%) healed

in an average treatment time of 22 weeks (median, 17 weeks). Stratification of the healed and failed outcome for age, gender, concomitant disease, bone location, fracture age, prior last surgery interval, nonunion type, smoking habits, and fixation before and during treatment showed a significant difference only in the smoking habit strata. CONCLUSION: Noninvasive ultrasound therapy can be useful in the treatment of challenging, established nonunions.

PMID: 11586161 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

2002

1: Unfallchirurg. 2002 Feb;105(2):108-15.
Is low intensity ultrasound effective in treatment of disorders of fracture healing
Mayr E, Mockl C, Lenich A, Ecker M, Ruter A.
Klinik fur Unfall- und Wiederherstellungs-chirurgie, Zentralklinikum Augsburg, Stenglinstrasse 2, 86156 Augsburg. Edgar-Barbara-Mayr@t-online.de

This prospective consecutive study judges the effectiveness of pulsed low-intensity ultrasound for treatment of boney healing disorders. 86 out of 100 treatments were successful. Although in these 100 cases 64 delayed unions and 36 nonunions were enrolled ultrasound therapy was performed as an alternative to the indicated operation in every case. Excluding ten cases of ununited fractures of the scaphoid no additional therapy was performed in any case. Stratifying the data no significant differences in healing rate and treatment time were observed between delayed unions and non-unions and between atrophic and hypertrophic healing disorders. Judging the healing rate of 86% one has to take into consideration that according to our in- and excluding criteria we had a preselected sample of patients. Nevertheless the effectiveness of pulsed low-intensity ultrasound for treatment of disorders of the fracture repair process is evident.

PMID: 11968536 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: CMAJ. 2002 Feb 19;166(4):437-41.
Comment in: CMAJ. 2002 Jul 23;167(2):128; author reply 128. Clin J Sport Med. 2003 Mar;13(2):127.
The effect of low-intensity pulsed ultrasound therapy on time to fracture healing: a meta-analysis.
Busse JW, Bhandari M, Kulkarni AV, Tunks E.
Oncidium Health Group Inc., Burlington, Ont. j.busse@utoronto.ca

BACKGROUND: The effect of low-intensity ultrasonography on fracture healing is controversial, and current management of fractures does not generally involve the use of ultrasound therapy. We describe a systematic review and meta-analysis of randomized controlled trials of low-intensity pulsed ultrasound therapy for healing of fractures. METHODS: We searched 5 electronic databases (MEDLINE, EMBASE, Cochrane Database of Randomised Clinical Trials, HealthSTAR and CINAHL) for trials of ultrasonography and fracture healing, in any language, published from 1966 to December 2000. In addition, selected journals published from 1996 to December 2000 were searched by hand for relevant articles, and attempts were made to contact content experts in the area of ultrasound therapy and fracture healing as well as primary authors of reviewed trials.

Trials selected for review met the following criteria: random allocation of treatments; inclusion of skeletally mature patients of either sex with 1 or more fractures; blinding of both the patient and the assessor(s) as to fracture healing; administration of low-intensity pulsed ultrasound treatments to at least 1 of the treatment groups; and assessment of time to fracture healing, as determined radiographically by bridging of 3 or 4 cortices. Two reviewers independently applied selection criteria to blinded articles, and selected articles were scored for methodologic quality. The internal validity of each trial was assessed with the use of a 5-point scale that evaluates the quality of trial method on the basis of description and appropriateness of randomization and double-blinding, and assessment of study withdrawals and likelihood of bias. RESULTS: We identified 138 potentially eligible studies, of which 6 met our inclusion criteria. Agreement beyond chance of quality assessments of the 6 trials was good (intraclass correlation coefficient 0.77, p = 0.03). One trial was a repeat analysis of previously reported data, and 2 trials appeared to report on a shared group of subjects. Three trials, representing 158 fractures, were of sufficient homogeneity for pooling. The pooled results showed that time to fracture healing was significantly shorter in the groups receiving low-intensity ultrasound therapy than in the control groups. The weighted average effect size was 6.41 (95% confidence interval 1.01-11.81), which converts to a mean difference in healing time of 64 days between the treatment and control groups. INTERPRETATION: There is evidence from randomized trials that low-intensity pulsed ultrasound treatment may significantly reduce the time to fracture healing for fractures treated nonoperatively. There does not appear to be any additional benefit to ultrasound treatment following intramedullary nailing with prior reaming. Larger trials are needed to resolve this issue.

PMID: 11873920 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=11873920

2003

Low-intensity, pulsed ultrasound and its influence on bone regeneration
Clinical results and scientific background
Esenwein SA, Hopf KF, Dudda M, Pommer A, Kutscha-Lissberg F, Muhr G

Abstract:
Bone healing can be accelerated by the use of low-intensity, pulsed ultrasound. This article offers an overview of the possibilities for its clinical application as well as its scientific basics as far as its effect mechanism is concerned. Apart from experiences cited in the literature, our own experimental and clinical treatment results are also demonstrated. The results presented show a stimulatory effect of low-intensity, pulsed ultrasound on fracture healing. In our opinion, the clinical application of low-intensity, pulsed ultrasound is indicated especially in borderline situations such as callus distraction and the therapy of pseudarthrosis.

http://www.springerlink.com/content/3md9p1rc7c8hmk90/fulltext.html

2004

Knochen heilen rasch mit Ultraschall-Stimulation
Niederenergetischer gepulster Ultraschall für Anwendung zu Hause / Option besonders bei Bruchheilungsstörungen

Mit Ultraschallwellen können Knochen schneller und besser heilen als ohne diese Behandlung. Davon sind Dr. Stefan A. Esenwein von der Ruhr-Uni Bochum und seine Kollegen überzeugt.
Esenwein Stefan, Ärzte Zeitung, 22.12.2004
Quelle: http://www.aerztezeitung.de/docs/2004/12/22/234a0601.asp

Low-intensity pulsed ultrasound and its influence in healing of fresh fractures.
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Category Unfallchirurgie aktuell
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Edgar Mayr, Axel Rüter

Abstract
In the past several studies have shown a stimulant effect of low-intensity ultrasound (frequency: 1.5 MHz, pulsed with 1 KHz, signal burst width: 200 ws, intensity: 30 mW/cm^2, period of stimulation: 20 min/day) on fresh fracture healing. Our question was whether this therapy could also shorten the treatment time for scaphoid fractures. Within the context of a prospective randomized study we examined the hypothesis that 80% of such fractures would heal in less than 8 weeks when low-intensity ultrasound was applied, while without ultrasound only 20% of scaphoid fractures would heal within 8 weeks. The sample size calculation culminated in two random groups of 15 patients each. Only patients with stable scaphoid waist fractures were enrolled in the study. For group I patients treatment took the standard form of application of a forearm cast including the thumb, which was left in place until the fractures were healed. Group II patients each received a 20-min ultrasound treatment daily in addition. Healing was assessed by longitudinal CT of the scaphoid, which was performed every 2 weeks from the 4th week after injury onward. From 01.01.1996 to 20.04.1998 treatment of 30 stable scaphoid fractures was completed. The average age of the patients was 37 - 14 years; there were 25 male and 5 female patients. In group I the time needed for healing was 62 - 19.2 days, while in group II healing took only 43.2 - 10.9 days (P = 0.0055). Whereas by day 65 the fractures of all the patients in group II were healed, only 60% of those in group I (controls) had achieved healing by this time point. A g-error of g = 0.0005 underlines the high reliability of the study. Three independent investigators blinded to the study conditions assessed the CT scans to test the results. Our study results are in keeping with numerous others showing the stimulating effect of low-intensity ultrasound on fracture healing. In the case of scaphoid fractures this therapy is beneficial to patients, physicians and insurance companies because of the long healing times under standard conditions. CT is a reliable method of assessing healing, allowing much earlier asessment than standard X-rays.

1: J Orthop Res. 2004 Mar;22(2):395-403.
Effects of timing of low-intensity pulsed ultrasound on distraction osteogenesis.
Sakurakichi K, Tsuchiya H, Uehara K, Yamashiro T, Tomita K, Azuma Y.
Department of Orthopaedic Surgery, School of Medicine, Kanazawa University, 13-1 Takara-machi, Kanazawa 920-8641, Japan.

We investigated the effects of low-intensity pulsed ultrasound (LIPUS; 30 mW/cm2 spatial and temporal average) on the timing of LIPUS treatment in distraction osteogenesis. Lengthening of the right tibia was performed in 75 male Japanese white rabbits using unilateral fixators (waiting period, 7 days; distraction rate, 1.5 mm/day; distraction period, 7 days). Rabbits were divided into four groups according to the timing of the LIPUS treatment. Control group had no stimulation. Waiting group was treated with a daily 20-min session of LIPUS during a 7-day latency period. Lengthening group was treated during the lengthening period. Maturation group was treated for the first 7 days after completion of distraction. We evaluated the distraction site by radiography and histology every week for 4 weeks. Bone mineral density (BMD) and mechanical strength were tested and microfocus X-ray computed tomography was performed on specimens 2 weeks after completion of distraction. The lengthening group had greater BMD and mechanical strength than the other groups, bone regeneration was enhanced more in the maturation group than in the control or waiting groups. Histologically, endochondral bone formation in the lengthening and the maturation groups occurred earlier than in the control or waiting groups. These results suggest the LIPUS effect is mediated via endochondral pathways. We concluded that LIPUS stimulates bone formation in distraction osteogenesis and is most effective during the lengthening phase.

PMID: 15013102 [PubMed - indexed for MEDLINE]

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=15013102&query_hl=10&itool=pubmed_docsum

1: J Bone Joint Surg Am. 2004 Nov;86-A(11):2399-405. Links
Low-intensity pulsed ultrasound accelerates maturation of callus in patients treated with opening-wedge high tibial osteotomy by hemicallotasis.
Tsumaki N, Kakiuchi M, Sasaki J, Ochi T, Yoshikawa H.
Department of Orthopaedics, Osaka University Graduate School of Medicine, 2-2 Yamadaoka, Suita, Osaka 565-0871, Japan. tsumaki-n@umin.ac.jp

BACKGROUND: Opening-wedge high tibial osteotomy by hemicallotasis for osteoarthritis in the medial compartment of the knee requires external fixation for a long time, until callus maturation is complete. The aim of this study was to determine if low-intensity pulsed ultrasound would accelerate callus maturation when applied after distraction to limbs treated with opening-wedge high tibial osteotomy by hemicallotasis. METHODS: Twenty-one patients with symmetric grades of osteoarthritis and similar degrees of varus deformity in the two knees underwent bilateral one-stage opening-wedge high tibial osteotomy by hemicallotasis. After completion of distraction, the bone mineral density of the distraction callus was measured. Then, one randomly selected limb was subjected to ultrasound treatment for twenty minutes daily until removal of the external fixator. The contralateral limb was left untreated to serve as the control. After four weeks of treatment, bone mineral density was measured again. RESULTS: During the four-week treatment period, the mean increase in callus bone mineral density was significantly greater in the ultrasound-treated

tibiae (0.20 +/- 0.12 g/cm(2)) than in the control tibiae (0.13 +/- 0.10 g/cm(2)) (p = 0.02, unpaired t test). In eighteen patients the increase in the bone mineral density was greater in the ultrasound-treated limb than in the control limb, whereas in three patients the increase was greater in the control limb. CONCLUSIONS: We found that low-intensity pulsed ultrasound applied during the consolidation phase of distraction osteogenesis accelerates callus maturation after opening-wedge high tibial osteotomy by hemicallotasis in elderly patients.

PMID: 15523009 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=15523009&query_hl=10&itool=pubmed_docsum

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Complex tibial fracture outcomes following treatment with low-intensity pulsed ultrasound

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Abstract
A clinical study was conducted to investigate the effect of low-intensity pulsed ultrasound (US) stimulation (LIPUS) on the healing of complex tibial fractures. Thirty complex tibial fractures were randomly assigned to the treatment with LIPUS (n = 16) or by a dummy machine (sham-exposed: n = 14). The fractures were immobilized by either internal or external fixations according to the clinical indications. LIPUS was given 20 min/day for 90 days. Fracture healing was monitored by clinical, radiological, densitometric and biochemical assessments. The LIPUS-treated group showed statistically significantly better healing, as demonstrated by all assessments. Complications were minimal in the LIPUS group. There were two cases of delayed union, with one in each group. There were two cases of infection in the control group. The delayed-union cases were subsequently treated by LIPUS and the infection cases were treated with standard protocol. Fracture healing in these patients was again treated by LIPUS. (E-mail: ksleung@cuhk.edu.hk)

Author Keywords: Author Keywords: Low-intensity pulsed ultrasound; Complex tibial fracture; Bone mineral content; Densitometry; Alkaline phosphatase

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http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TD2-4C2HHGB-G&_user=10&_coverDate=03%2F31%2F2004&_alid=538466017&_rdoc=6&_fmt=summary&_orig=search&_cdi=5186&_sort=d&_docanchor=&view=c&_ct=6&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=37e5d01b71defae4117fc011da435033

1: Ultrasonics. 2004 Apr;42(1-9):915-7.

Compound high-energy limb fractures with delayed union: our experience with adjuvant ultrasound stimulation (exogen).

Lerner A, Stein H, Soudry M.
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The use of low intensity pulsed ultrasound accelerates cortical and cancellous bone fracture healing. Seventeen patients with eighteen high-energy fractures of the long bones were treated with low intensity pulsed ultrasound supplementation to surgical skeletal stabilization and tissue flaps. Sixteen fractures were healed within 13-52 weeks after starting ultrasound supplementation despite severe soft-tissue injuries and varying degrees of tissue loss. This method may be useful in the combined treatment of high-energy limb injuries.

PMID: 15047406 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: Ultrasound Med Biol. 2004 Mar;30(3):389-95.

Complex tibial fracture outcomes following treatment with low-intensity pulsed ultrasound.

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A clinical study was conducted to investigate the effect of low-intensity pulsed ultrasound (US) stimulation (LIPUS) on the healing of complex tibial fractures. Thirty complex tibial fractures were randomly assigned to the treatment with LIPUS (n = 16) or by a dummy machine (sham-exposed: n = 14). The fractures were immobilized by either internal or external fixations according to the clinical indications. LIPUS was given 20 min/day for 90 days. Fracture healing was monitored by clinical, radiological, densitometric and biochemical assessments. The LIPUS-treated group showed statistically significantly better healing, as demonstrated by all assessments. Complications were minimal in the LIPUS group. There were two cases of delayed union, with one in each group. There were two cases of infection in the control group. The delayed-union cases were subsequently treated by LIPUS and the infection cases were treated with standard protocol. Fracture healing in these patients was again treated by LIPUS.

PMID: 15063521 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: Zentralbl Chir. 2004 Oct;129(5):413-20.

Efficiency of low-intensity pulsed ultrasound on distraction osteogenesis in case of delayed callotasis -- clinical results [Article in German]

Esenwein SA, Dudda M, Pommer A, Hopf KF, Kutscha-Lissberg F, Muhr G.
Berufsgenossenschaftliche Kliniken Bergmannsheil, Chirurgische Universitatsklinik der Ruhr-Universitat Bochum, Bochum. Stefan.A.Esenwein@ruhr-uni-bochum.de

AIM: Low-intensity pulsed ultrasound has been proven to accelerate fracture healing both clinically and experimentally. In this study the influence of low-intensity pulsed ultrasound during distraction-osteogenesis in case of delayed callotasis was investigated. METHOD: 20 patients could be included in this study. 16 patients initially were treated because of fractures of the lower leg, 2 because of fractures of the femur with resulting shortening of the afflicted limb. One patient suffered from chronic osteitis at the thigh and one from chronic osteitis at the upper arm without previous trauma. Because of delayed callotasis an adjunctive ultrasound treatment device was transcutaneously applied (frequency 1.5 MHz, signal burst width 200 microseconds, signal repetition frequency 1.0 kHz, intensity 30 mW/cm (2)) with the transducer placed at the distraction zone for 20 minutes daily. In all cases in-home treatment was performed. Evaluation was done by radiographic and sonographic controls of the distraction zone during examination of all patients at the outpatients' department every 3-4 weeks. RESULTS: Progress of callotasis was achieved in 15 out of 20 patients. Patients who were smokers during ultrasound therapy showed lower healing rates than those who never smoked. 2 patients suffering from osteitis of the tibia and missing callotasis had to be amputated. 3 other patients needed additional operative treatment including cancellous bone grafts because of missing new bone formation. Negative effects of low-intensity pulsed ultrasound during therapy could not be detected. CONCLUSION: We conclude that ultrasound treatment can accelerate bone maturation and formation in distraction osteogenesis, sometimes even in states of poor callotasis. It may provide a method of great promise in cases where delayed bone formation during distraction osteogenesis occurs.

PMID: 15486796 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=15486796

2005

Unfallchirurg. 2005 Jan;108(1):69-74. PubMed-ID: 15241607

Anwendung von niederenergetischem gepulstem Ultraschall bei der Kallusdistraktion am Humerus. Fallbeispiel.

Dudda M, Pommer A, Muhr G, Esenwein SA : 2005 Jan

1. Chirurgische Klinik mit Poliklinik, Berufsgenossenschaftliche Kliniken Bergmannsheil, Ruhr-Universität, Bochum
2. HELIOS-Klinikum GmbH, Klinikum der Universität Witten/Herdecke, Klinik für Unfall- und Wiederherstellungschirurgie, Wuppertal
3. Chirurgische Klinik mit Poliklinik, Berufsgenossenschaftliche Kliniken Bergmannsheil, Ruhr-Universität, Bürkle-de-la-Camp-Platz 1, 44789 Bochum

Zusammenfassung: Durch die Anwendung von niederenergetischem gepulstem Ultraschall konnte sowohl klinisch als auch experimentell eine Beschleunigung der Frakturheilung nachgewiesen werden. Anhand von bisher publizierten tierexperimentellen Ergebnissen geht man außerdem von einer Verbesserung der Regeneratreifung nach Kallusdistraktion durch die Anwendung von niederenergetischem gepulstem Ultraschall aus.

Wir berichten über den Fall einer 18-jährigen Patientin mit einer erworbenen Verkürzung des rechten Oberarms von 10 cm Länge nach abgelaufener Osteitis des Humerus im Säuglingsalter. Die Patientin stellte sich bei bestehendem Operationswunsch zur Durchführung einer Kortikotomie mit Kallusdistraktion am Humerus in unserem Hause vor.
Da aufgrund der publizierten tierexperimentellen Ergebnisse von einer Verbesserung der Regeneratreifung durch die Anwendung von niederenergetischem, gepulstem Ultraschall bei dieser Patientin ausgegangen werden konnte, entschlossen wir uns zur Anwendung dieses Therapieverfahrens. Der rechnerisch ermittelte Distraktions-Konsolidierungs-Index betrug in dem präsentierten Fall 21 Tage/cm und liegt damit deutlich unter dem aus der Literatur bekannten Mittelwert von 30 Tage/cm für Kallusdistraktionen am Humerus. Der ebenfalls rechnerisch ermittelte Verlängerungsindex nach Paley betrug in dem präsentierten Fall 0,7 Monate/cm. Vergleicht man diesen Wert mit den Referenzwerten aus der wissenschaftlichen Literatur, die von 0,87–1,5 Monaten/cm ausgehen, so wird die beschleunigte Regeneratreifung in dem berichteten Fall erkennbar. Die Behandlungsdauer der Patientin konnte somit durch die Ultraschallanwendung im Vergleich zu den bekannten Referenzwerten aus der Literatur deutlich verkürzt werden.
Bei korrekter Indikationsstellung zur Kallusdistraktion ist demnach eine frühzeitige Anwendung von niederenergetischem gepulstem Ultraschall in Erwägung zu ziehen, da sich hierdurch eine Beschleunigung der Kallusreifung mit konsekutiver Verkürzung der Fixateurtragedauer und somit auch eine Verringerung kumulativer Komplikationen, wie z. B. Pininfekte, erzielen ließe. Weitere Studien unserer Arbeitsgruppe zu diesem Themengebiet werden folgen.

Quelle: http://www.springerlink.com/content/fxpd5a6de67ye8md/?p=778fa7a49aa746039257634ce1a30ab7&pi=1
bzw. http://www.bergmannsheil.de/index.php?refid=15241607&id=254&L=0&year_low=1980&year_high=2006&dept=Chirurgische+Klinik&author=&text_string=Ultraschall

1: J Pediatr Orthop. 2005 Nov-Dec;25(6):750-4.
Pulsed low-intensity ultrasound: a new salvage procedure for delayed unions and nonunions after leg lengthening in children.
Gebauer D, Correll J.
Orthopedic Clinic Tegernsee, Tegernsee, Germany. dieter.gebauer@lva-landshut.de

From 1998 to 2001, 112 lengthening procedures with or without deformity correction were performed in 108 children by external fixation with the Ilizarov method. Of these cases, 16.9% did not lead to a solid bone consolidation. Two children were operated the second time, mainly because of the parent's decision. Seventeen delayed unions or nonunions in 13 children were treated with low-intensity pulsed ultrasound. All 17 cases healed within 3 to 12 months without any risk of surgical intervention.

PMID: 16294131 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=16294131

1: Ultrasound Med Biol. 2005 Oct;31(10):1391-402.
Low-intensity pulsed ultrasound: effects on nonunions.
Gebauer D, Mayr E, Orthner E, Ryaby JP.
Orthopadische Klinik Tegernsee, Tegernsee, Germany. dieter.gebauer@lva-landshut.de

To study the efficacy of low-intensity pulsed ultrasound (US), or LIPUS, of 85 treated nonunion cases with a minimum fracture age of 8 months, 67 cases met the study criteria. These were: no surgical intervention during 4 months before US treatment and radiographically ceased healing for 3 months before US. In a self-paired control study, the mean fracture age of the 67 patients was 39 +/- 6.2 months. After a daily 20-min US treatment at home for an average of 168 days, 85% (57 of 67) of the nonunion cases were clinically and radiographically healed. The study did not include any cases that were malaligned, grossly instable, actively infected or that had extensive bone loss. The results demonstrate that the specific US can effect heal rates similar to those achieved by surgical means, without the associated risks and complications, and to those achieved by electrical bone growth stimulation or by extracorporeal shock-wave therapy.

PMID: 16223643 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?itool=abstractplus&db=pubmed&cmd=Retrieve&dopt=abstractplus&list_uids=16223643

1: J Orthop Trauma. 2005 Jan;19(1):10-6.
Preliminary results of tibial bone transports with pulsed low intensity ultrasound (Exogen).
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OBJECTIVE: This study assessed whether the use of noninvasive, pulsed low intensity ultrasound (Exogen) reduced external fixation time for bone transport patients with large, segmental tibial defects. DESIGN: This was a prospective study compared to a previously treated control group. SETTING: All surgeries and postoperative care were done at the senior author's hospital facilities. PATIENTS/PARTICIPANTS: Eight patients with large tibial segmental defects, acute or chronic, were studied. All patients were male, mean age 34 years (range 18-50). INTERVENTION: All patients were treated with a single-level bone transport. Bone transports started 5 to 10 days after a metaphyseal corticotomy and progressed with one-quarter millimeter advancement 2 to 4 times per day. Exogen was applied to the regenerate site in the second postoperative week and to the docking site after docking was complete. The treatment was used for 20 minutes daily at each site. The patients were followed weekly for the first 4 weeks. They were then followed bimonthly for 2 months and then monthly until consolidation had occurred. MAIN OUTCOME MEASURES: The 2 main outcome measures used were the external fixation time measured in months and the external fixation index (time in the frame per cm of bone transported) measured in months per cm. RESULTS: The mean follow-up from frame removal to the time of the last clinic visit was 12.4 months (range 4-32). The mean external fixation time was 13.91. The mean external fixation index was 1.34 months per cm transported for the Exogen group and 2.02 months per cm for the control group. Although not statistically significant because of small numbers, the external fixation index was reduced by 17.21%. CONCLUSION: These data further confirm already published data on the acceleration of fracture healing by low intensity pulsed ultrasound and, in our case, regenerate consolidation. Shorter treatment periods reduce complications and expenses and return patients back to regular activities more quickly.

PMID: 15668578 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: Int Orthop. 2005 Apr;29(2):121-4. Epub 2005 Feb 1.

The effect of low-intensity pulsed ultrasound on callus maturation in tibial distraction osteogenesis.

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Callus distraction is currently the most popular method of bone lengthening. Prolonged treatment time is one of its major problems. In this study, we investigated the effect of low-intensity pulsed ultrasound on tibial distraction osteogenesis. We managed 20 patients with tibial defects ranging from 5 cm to 8 cm with distraction osteogenesis using the Ilizarov external fixator. After the completion of distraction, ten patients received daily 20 min of low-intensity pulsed ultrasound stimulation (30 mW/cm2) onto the bone lengthening site (group A) while rigid fixation was maintained in the remaining patients (group B). All patients were followed with weekly radiographs to determine the formation of an external cortex and an intramedullary canal, at which time the fixator was removed. The mean healing index in group A was 30 (27-36) days/cm while it was 48 (42-75) days/cm in group B. In group B, one patient failed to consolidate the regenerated bone. Low-intensity pulsed ultrasound stimulation is highly effective in achieving maturation of bone and reducing time of distraction osteogenesis.

PMID: 15685456 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=15685456&query_hl=13&itool=pubmed_docsum

1: Clin Orthop Relat Res. 2005 Jan;(430):189-94.

Low-intensity ultrasound enhances maturation of callus after segmental transport.

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The purpose of this study was to determine whether low-intensity ultrasound can be used to enhance callus maturation. Fifteen-millimeter bone defects at the metatarsal bones of sheep were treated with a segmental bone transport for 16 days. The callus formations in the bone defects were allowed to mature for 63 days before the animals were sacrificed. Eighteen sheep were operated on and divided into two groups. One group was treated with low-intensity ultrasound for 20 minutes per day, whereas the other group served as an untreated control group. Biomechanical tests after removal of the metatarsals showed significantly higher axial compression stiffness and significantly higher indentation stiffness of callus tissue in the healing zone in the group treated with ultrasound. Also, histologic analysis of the cortical defect zone showed significantly more callus formation and more active zones of endochondral ossification in the group treated with ultrasound. Stimulation of callus maturation by ultrasound is possible, similar to stimulation of fresh fracture healing, and may be used to shorten clinical treatment times.

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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=15662323&query_hl=15&itool=pubmed_DocSum

1: Arch Orthop Trauma Surg. 2005 Jun;125(5):317-21. Epub 2005 Apr 9.

The effect of low intensity ultrasound and bioabsorbable self-reinforced poly-L-lactide screw fixation on bone in lateral malleolar fractures.

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INTRODUCTION: There are no previous reports of low intensity pulsed ultrasound therapy in connection with bioabsorbable fracture fixation. In this randomised, prospective, double-blind and placebo-controlled study, the effects of ultrasound on bone mineral density and bone healing were examined in lateral malleolar fractures fixed with a bioabsorbable self-reinforced poly-L-lactide screw (SR-PLLA). MATERIALS AND METHODS: Thirty adult patients with SR-PLLA screw-fixed lateral malleolar fracture underwent ultrasound therapy 20 min daily for 6 weeks. Half of the patients were provided randomly with a sham ultrasound device. Bone mineral density and bone healing were assessed by dual-energy X-ray absorptiometry (DXA) and by radiographs. RESULTS: Bone mineral density of the fractured lateral malleolus tended to increase slightly during 12 weeks of follow-up. The increase was symmetrical and statistically non-significant between the ultrasound and non-ultrasound group. All the fractures healed uneventfully. The biocompatibility of the bioabsorbable SR-PLLA fixation device and low intensity pulsed ultrasound was good. Despite the slight tendency for more frequent callus formation in the ultrasound group, no statistically significant effect of low intensity pulsed ultrasound on lateral malleolar fracture healing could be observed. CONCLUSION: It was not possible to observe any statistically significant effect of low intensity pulsed ultrasound on lateral malleolar fracture healing in this study. Further studies are needed to examine the role of ultrasound therapy in the healing of fractures treated with bioabsorbable fixation devices.

PMID: 15821899 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: J Orthop Sci. 2005 Jul;10(4):391-5.

Effect of ultrasound therapy on bone healing of lateral malleolar fractures of the ankle joint fixed with bioabsorbable screws.

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BACKGROUND: We investigated the effect of low-intensity ultrasound on bone healing in bioabsorbable self-reinforced poly-L: -lactic acid (SR-PLLA) screw-fixed lateral malleolar fractures. The study design was prospective, randomized, double-blind, and placebo-controlled. METHODS: A total of 22 fractures were fixed with one SR-PLLA screw. All the patients were instructed to use an ultrasound device 20 min daily for 42 days without knowing whether it was active or inactive. Eleven patients had active and eleven sham ultrasound devices. The causes of error during treatment with head module placement and attachment to the convex surface of the lateral distal fibula were minimized by careful targeting and using coupling gel. Radiological fracture healing was assessed by radiographs and multidetector computed tomography (CT) scans in a blinded manner by a radiologist and orthopedic surgeons. RESULTS: The overall compliance to the daily ultrasound treatments was good. All wounds healed uneventfully, and no foreign body reactions were observed. No difference was observed between the groups regarding either fracture line visualization or callus formation assessed by plain radiographs. In the CT images at 9 weeks, the share of the endosteal united fracture line compared to the non-united fracture line was slightly higher in the active ultrasound device group than in the sham ultrasound device group, but the difference was not statistically significant. CONCLUSION: The study indicates that the

biocompatibility of ultrasound therapy and bioabsorbable SR-PLLA screw fixation is good. There was no obvious effect of low-intensity ultrasound on lateral malleolar fracture healing. However, the relatively small number of patients must be kept in mind when interpreting our results. It is also important to limit any conclusions based on the present study to malleolar fractures fixed with the SR-PLLA screw.

PMID: 16075172 [PubMed - indexed for MEDLINE]
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=File&DB=pubmed

1: Orthopedics. 2005 Oct;28(10):1161-3.
How does pulsed low-intensity ultrasound enhance fracture healing?
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Pulsed low-energy ultrasound, a non-invasive therapeutic treatment modality, may improve callus formation and enhance fracture healing by initiating enhanced angioneogenesis.

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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=16237880&itool=iconabstr&query_hl=2&itool=pubmed_DocSum

The effect of ultrasound on the healing of muscle-pediculated bone graft in scaphoid non-union
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Abstract/Zusammenfassung
The use of pedicled vascularised bone grafts from the distal radius makes it possible to transfer bone with a preserved circulation and viable osteoclasts and osteoblasts. Experiments performed at the basic science level has provided substantial evidence that low-intensity ultrasound can accelerate and augment the fracture healing process. Only an adequate double-blind trial comparing treatment by ultrasound stimulation in patients treated by similar surgical techniques can provide evidence of the true effect of ultrasound. This paper describes the results of such a trial. From 1999 to 2004, 21 fractures of the scaphoid with established non-union treated with vascularised pedicle bone graft were selected for inclusion in a double-blind trial. All patients were males, with an average age of 26.7 years (range 17–42 years) and an average interval between injury and surgery of 38.4 months (range 3 months–10 years). Low-intensity ultrasound was delivered using a TheraMed 101-B bone-growth stimulator (30 mW/cm^2, 20 min/day), which was modified to accomplish double-blinding. These modifications did not affect the designated active units. The placebo units were adjusted to give no ultrasound signal output across the transducer. Externally, all units appeared identical but were marked with individual code numbers. Patients were randomly allocated to either an active or placebo stimulation. Follow-up averaged 2.3 years (range 1–4 years). All patients achieved fracture union (active and placebo groups), but compared with the placebo device (11 patients), the active device (ten patients) accelerated healing by 38 days (56±3.2 days compared with 94±4.8 days, p<0.0001, analysis of variance).
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2532075/

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Effects of ultrasound and infrasound relevant to human health - The enhancement of bone regeneration by ultrasound

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Available online 10 August 2006.

Abstract
Millions of fractures occur every year worldwide, with nearly 6.2 million fractures reported annually in the United States alone. Even though treatment methods have improved over the last few decades, 5–10% of fractures still show delayed healing. A significant subpopulation of these delayed healings do not heal by nine months and are thus termed non-unions. Experimental studies have shown some evidence that low intensity pulsed ultrasound stimulation (LIPUS) results in enhanced bone regeneration during fracture healing and callus distraction. LIPUS treatment has led to increased callus area and accelerated return of bone strength following fracture. Histological studies suggest that LIPUS influences all major cell types involved in bone healing, including osteoblasts, osteoclasts, chondrocytes and mesenchymal stem cells. The affect of LIPUS seems to be limited to cells in soft tissue, whereas cells in calcified bone seem not to be effected. In vitro cell culture studies as well as tissue culture studies have shown some effects on cell differentiation and protein synthesis. Even though the energy used by LIPUS treatment is extremely low, the effects are evident. The most probable source of the therapeutic benefits observed with LIPUS treatment involves nonthermal mechanisms that influence cell membrane permeability and increase cellular activity. Despite clinical and experimental studies demonstrating the enhancing effect of LIPUS on bone regeneration, the biophysical mechanisms involved in the complex fracture healing process remain unclear and requires further research.

Keywords: Fracture; Healing; Ultrasound; Distraction osteogenesis; Review
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TBN-4KM3WCW-4&_user=10&_coverDate=04%2F30%2F2007&_alid=538466017&_rdoc=1&_fmt=summary&_orig=search&_cdi=5147&_sort=d&_docanchor=&view=c&_ct=6&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=14e39402ecb21bee8ef3a716cb6ef65d

1: J Orthop Res. 2006 Feb;24(2):263-70.

Low intensity pulsed ultrasound accelerated bone remodeling during consolidation stage of distraction osteogenesis.

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Bone regeneration in distraction osteogenesis occurs under tensile stress with axial rhythmic distraction after osteotomy. In this study, we evaluated if the low intensity pulsed ultrasound (LIPUS) was also effective on enhancement of bone remodeling during consolidation stage of distraction osteogenesis. Open osteotomy of seventeen 18-week-old female New Zealand rabbit tibiae were performed. The distraction was applied with the rate of 1 mm per day. LIPUS (30 mW/cm(2), 1.5 MHz) was delivered for 20 min per day during 4-week consolidation stage (n=10).

The animals without treatment served as sham group (n=7). Plain X-ray, peripheral quantitative computational tomography (pQCT), and torsional test were performed. Results showed that smaller radiolucent interzone of LIPUS treatment group was gradually occupied by calcified tissue in plain X-ray at week 2. The bone mineral density (BMD) measured on radiographs increased by 9.18% in the LIPUS group. Bone mineral content (BMC), hard callus volume, and bone strength index (BSI) measured by pQCT were 83%, 116%, and 94%, respectively, in LIPUS group that were significantly greater than those of the controls. At the 4th week, LIPUS-treated callus showed the development of neocorticalization in the proximal and distal region. The BMC, hard callus volume, and BSI of LIPUS group decreased and was not significantly different from control. This was also confirmed by the maximum torque of LIPUS-treated callus (1424.2+/-457.3 N . mm) obtained at week 4, which did not differ from that of the sham group (1968.8+/-895.1 N . mm). In conclusion, the effective period of LIPUS treatment was at the initial stage of consolidation, with accelerated bone formation and remodeling. (c) 2005 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. J Orthop Res.

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http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=16435359&query_hl=16&itool=pubmed_DocSum

1: J Orthop Res. 2006 Nov;24(11):2072-9.

Dose-dependent effect of low-intensity pulsed ultrasound on callus formation during rapid distraction osteogenesis.

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Distraction osteogenesis of bone or callotasis causes poor bone formation when the distraction rate is beyond the optimal rate. Low-intensity pulsed ultrasound was reported to enhance fracture healing, treatment of nonunion, and accelerate bone maturation and remodeling during consolidation stage of distraction osteogenesis. In this study, we evaluated the efficacy of different durations of LIPUS treatments during rapid bone lengthening. After 7-day latent period, osteotomized New Zealand white rabbit tibiae were lengthened at the rate of 2 mm per day for 1 week. Two different LIPUS treatment durations of 20 min and 40 min were selected for treatment groups. Rabbits without treatment served as the control group. Plain X-ray, peripheral quantitative computed tomography (pQCT) and histology were performed to assess bone acquisition in the distraction callus. The results showed that LIPUS increased bone mineral content and volume of the mineralized tissue of distraction callus in a dose-dependent manner. The different regions of distraction callus exhibited various spatial response to LIPUS treatment. Moreover, LIPUS enhanced dose-dependant endochondral formation. Compared with 20-min treatment, the 40-min LIPUS treatment was a more favorable treatment duration for bone regeneration in the distraction callus. In conclusion, LIPUS was able to enhance bone regeneration under rapid distraction, and its effect was dose-dependent. Copyright (c) 2006 Orthopaedic Research Society.

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Low-intensity pulsed ultrasound accelerates osteogenesis at bone-tendon healing junction

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Abstract
This study was designed to evaluate low-intensity pulsed ultrasound (LIPUS) in acceleration of mineralization and remodeling of the new bone formed at the healing interface of bone-tendon junction. Thirty-two mature New Zealand white rabbits underwent partial patellectomy and direct repair of the patellar tendon and proximal patella. Animals were then divided into LIPUS treatment group (20 min/d, 5 times/wk) and placebo control group and were euthanized at week 8 and 16 postoperatively (n = 8, for each group and time point). The main outcome measures included new bone size and its bone mineral density (BMD). Results showed that the size of new bone was found to be 2.6 and 3.0 times significantly greater in the LIPUS group compared with that of the control group at weeks 8 and 16, respectively. In addition, the LIPUS group showed significantly higher BMD at week 8 than controls, but not at week 16. In conclusion, this was the first experimental study to show that LIPUS was able to enhance osteogenesis at the healing bone-tendon junction, especially before the postoperative week 8. Findings of this study formed a scientific basis for future clinical trials and establishment of indication of LIPUS for enhancing bone-tendon junction repair. (E-mail: Lingqin@cuhk.edu.hk)

Key Words: Low-intensity pulsed ultrasound; Bone-tendon junction repair; Bone remodeling; Bone mineral density; Histology

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http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TD2-4MJJDGY-G&_user=10&_coverDate=12%2F31%2F2006&_alid=538470994&_rdoc=16&_fmt=summary&_orig=search&_cdi=5186&_sort=d&_docanchor=&view=c&_ct=247&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=ac3f80405da3e00c0cfe7004927646bb

2007

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Low-intensity pulsed ultrasound treatment for postoperative delayed union or nonunion of long bone fractures.

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BACKGROUND: Postoperative delayed union and nonunion is the most common complication in fracture treatment. Recent studies have shown an accelerating effect of low-intensity pulsed ultrasound (LIPUS) on fracture repair. However, the indications for delayed union and nonunion are not clear. To clarify the factors which influence the effects of LIPUS, the data from a previous prospective multicenter study on LIPUS treatment for postoperative delayed union and nonunion of long bone fractures were reanalyzed. METHODS: Seventy-two cases of long bone fracture, including those of the femur, tibia, humerus, radius, and ulna, were analyzed. The mean time from the most recent operation to the beginning of LIPUS treatment was 11.5 (3-68) months. The relationship between the background factors and the union rate was analyzed using a logistic

regression method. In addition, long bone fractures in an upper extremity or in a lower extremity were analyzed separately. RESULTS: The union rate was 75% in all the cases of long bone fracture. There was a significant relationship between the union rate and the period from the most recent operation to the beginning of LIPUS treatment in all cases and in those that had long bone fracture of an upper extremity. There was also a significant relationship between the union rate and the time when a radiological improvement was first observed after the beginning of the treatment in all cases and in those with fractures in a lower extremity. When LIPUS treatment was started within 6 months of the most recent operation, 89.7% of all fractures healed. When an improvement in the radiological changes at the fracture site was observed after 4 months in those cases, then the sensitivity and specificity for union were more than 90%. CONCLUSIONS: LIPUS treatment should be started within 6 months of the most recent operation. Because LIPUS has been shown to be effective without causing either serious invasiveness or any undue risk to the patient, it may be considered the treatment of first choice for cases of postoperative delayed union or nonunion.
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http://www.springerlink.com/content/nu57538pu257628g/

1: J Mater Sci Mater Med. 2007 Feb 3; [Epub ahead of print]

The effect of low-intensity pulsed ultrasound on bone healing in SR-PLLA rod fixed experimental distal femur osteotomy in rat.

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The effects of low-intensity pulsed ultrasound (30 mW/cm(2)) were investigated in experimental cancellous bone fracture healing in bioabsorbable self-reinforced poly-L: -lactide (SR-PLLA) rod fixed distal femur osteotomy in rats. A transverse transcondylar osteotomy was fixed with one SR-PLLA rod in 32 male Wistar rats of the age of 20 weeks. Half of the rats had a daily 20-min ultrasound exposure for three weeks. The follow-up times were three, six, and 12 weeks. Radiographical, histological, microradiographical, oxytetracycline labeling, and histomorphometrical analyses were performed. No foreign-body reactions were noted. The biocompatibility of SR-PLLA and ultrasound was found to be good. In the radiological and histological assessments there was a slight tendency for enhanced healing in the ultrasound group at three weeks, but at six and 12 weeks no differences were observed. The histomorphometrical and oxytetracycline labeling analyses showed that ultrasound exposure had no significant effects on bone healing.The present study shows that there were no obvious findings to support the hypothesis that low-intensity pulsed ultrasound enhances bone healing in self-reinforced poly-L: -lactide (SR-PLLA) rod fixed experimental metaphyseal distal femur osteotomy in rats. The observed good biocompatibility provides a safe starting-point for clinical trials on bioabsorbable fixation combined with low-intensity ultrasound.

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Low-intensity pulsed ultrasound stimulates osteogenic differentiation in ROS 17/2.8 cells

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Abstract
There have been no studies investigating the effects of the mechanical stimulation provided by Low-intensity pulsed ultrasound (LIPUS) treatment on periodontal disease accompanying bone loss. LIPUS is known to accelerate mineralization and bone regeneration, but the precise cellular mechanism is unclear. Here, we investigated the effect of LIPUS on osteogenesis by examining the effect of LIPUS stimulation on cell proliferation, alkaline phosphatase (ALPase) activity, osteogenesis-related gene expression, and mineralized nodule formation in a rat osteosarcoma cell line. The cells were cultured in medium with or without the addition of LIPUS stimulation. The ultrasound signal consisted of 1.5 MHz at an intensity of 30 mW/cm2 for 20 min for all cultures. LIPUS stimulation did not affect the rate of cell proliferation. ALPase activity was increased at day 7 of culture after LIPUS stimulation. Real-time PCR analysis indicated that LIPUS significantly increased the expression of mRNA for the transcription factors Runx2, Msx2, Dlx5, and Osterix and for bone sialoprotein, whereas the mRNA expression of AJ18 was significantly reduced. The mineralized nodule formation and the calcium content in mineralized nodules were markedly increased on day 14 of culture after LIPUS stimulation. Our study demonstrates that LIPUS stimulation directly affects osteogenic cells, leading to mineralized nodule formation. In view of the widespread use of LIPUS for the clinical therapy of periodontal disease, it is likely that LIPUS has an important influence on key functional activities of osteoblasts in alveolar bone.

Keywords: Low-intensity pulsed ultrasound; Osteoblasts; Osteogenesis-related gene; Nodule formation

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T99-4MFSP1X-2&_user=10&_coverDate=02%2F13%2F2007&_alid=538470994&_rdoc=5&_fmt=summary&_orig=search&_cdi=5109&_sort=d&_docanchor=&view=c&_ct=247&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=78876a58bf2368222fb29ae25931da49

J Trauma. 2007 Apr;62(4):902-8.

Use of low-intensity pulsed ultrasound for posttraumatic nonunions of the tibia: a review of patients treated in the Netherlands.

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BACKGROUND: Low-intensity pulsed ultrasound is effective in fresh fracture healing, resulting in a 40% reduction in healing time. The aim of this study is to determine the effect of ultrasound treatment on established tibia nonunions. METHODS: The study group consists of all Dutch patients of posttraumatic consecutive nonunion of the tibia, who started their ultrasound treatment between January 2000 and February 2003. In total, 71 cases have been included, which involve 56 men and 15 women. Mean age was 40 years. Low-intensity pulsed ultrasound was the only new treatment. Strict criteria of enrollment minimized any spontaneous healing chance. According to literature, the spontaneous healing rate was between 5% and 30%. The study outcome, healed

or failed, was the primary efficacy parameter. Thirty percent was chosen to represent the maximum expected spontaneous healing and was the basis for statistical evaluation. Stratification was performed for the variables at the ultrasound treatment start.
RESULTS: The overall healing rate is 52 of 71 cases (73%). Ultrasound treatment shows a statistical significant higher healing rate compared with that of the spontaneous healing chance ($p < 0.0001$). Stratification shows no statistical significance for any of the variables analyzed. The long-term follow-up shows high compliance rate and no refractures. CONCLUSION: Tibia nonunions have a high occurrence rate and cause significant impairment to daily functioning. This study shows that low-intensity pulsed ultrasound is effective in the treatment of established tibia nonunions and can be seen as a good, safe, and cheaper alternative to surgery.
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Low-intensity pulsed ultrasound in the treatment of tibial non-union
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Abstract/Zusammenfassung
Non-union is still a major challenge to the orthopaedic surgeon and established non-union has zero probability of achieving union with out intervention. The purpose of this study was to evaluate the effect of low-intensity ultrasound in the treatment of tibial non-union. The study was done retrospectively by reviewing the case notes and radiographs. There were eight patients who received low-intensity pulsed ultrasound treatment as a treatment for tibial non-union. One patient who was noncompliant to the treatment was excluded from the study. Bony union was achieves in all the seven patients with an average healing time of 29 weeks (range 16–48 weeks). This study shows that low-intensity ultrasound is a simple and safe way to treat tibial non-unions.
http://www.springerlink.com/content/d44335730171602g/

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External adjuncts to enhance fracture healing: What is the role of ultrasound?
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Summary: Current methods of fracture care use various adjuncts aimed at decreasing time to fracture union and improving fracture union rates. Among the most commonly used modalities, low-intensity pulsed ultrasound is emerging as a safe, cost-effective and reliable treatment for both fresh fractures and fracture nonunions. Both in vivo and in vitro basic science studies have helped to elucidate potential mechanisms of ultrasound action and a number of prospective, randomised, doubleblind, placebo-controlled trials exist demonstrating the clinical efficacy of lowintensity pulsed ultrasound. This article will review the evidence for the use of low-intensity pulsed ultrasound in fracture care.