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20 years of Treatment of Bone Non-Unions and Delayed Unions with Shock Waves

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Abstract

The treatment of bone non-unions continues to be complex and prolonged in many cases. The advent of the use of mechanical waves has made it possible, through the phenomenon of mechanotransduction, to have a non-invasive tool with a low rate of complications.

This study analyzes the experience of the last 20 years with the use of shock waves.

Keywords: Non-union, shock waves, Delayed union, Mechanotransduction

Non-union is considered after 6 to 9 months from the initial trauma when signs of union are not present [1]. Despite current concepts in the surgical treatment of fractures with minimally invasive techniques and better fixation, approximately 5-10% of cases evolve with healing failure [2]. The treatment usually recommended in these cases is the replacement of the osteosynthesis material and placement of bone grafts, usually evolving with good results, however, in addition to the high cost, there may be complications such as pain, bleeding, hematoma, infection, and failure of healing. [3].

The treatment of non-unions and delayed unions using extracorporeal shock waves as an alternative to conventional surgical treatment has shown good results [4].

Treatment with extracorporeal shock waves is indicated to stimulate bone healing without the need for a new surgery, reducing risks and costs for patients. The procedure is indicated in cases in whom the reason for healing failure is of biological origin. It is not indicated when there is mechanical instability and when the focus gap is wider than five millimeters [4-7].

The treatment of non-unions with shock waves should preferably be performed with the so-called focused shock waves applying high energy. We started our practice in 1999 using this concept with good results [8].

Both focused and radial waves are able to stimulate osteoblast activity both in vitro and in animals. Both promote an effect called cavitation, which is the formation of intratissue-intertissued microbubbles, which are related to the stimulation of bone healing [9-11].

In the beginning, it was believed that only a mechanical force was causing stimulation of the periosteum, but animal and clinical studies have shown a series of chemical reactions involving osteoblasts, and the release o of tissue and vascular growth factors [12].

This phenomenon is described as mechanotransduction, i.e., a mechanical stimulus inducing a series of biological reactions, triggering the production of bone regenerative factors, increasing vascularization, and bone matrix production by osteoblasts [13, 14].

The actions of shock waves occur at the time of application with intense stimulation of the periosteum and in the following days with an increase in the local concentration of prostaglandins, tissue regeneration factors, increased production of osteoblasts and factors that increase vascularization, which can last for up to 3 months, which is the average time for bone healing to occur [6,14-17].

Animal studies have demonstrated the stimulation of osteoblasts and the formation of bone callus of good quality and resistance using both focused and radial waves [18, 19].

The presence of plates, screws, nails, and external fixators is not a contraindication because there is no heat reaction or risk of loosening due to mechanical stimulation;, on the contrary, the presence of osteosynthesis is necessary for the non-union focus to remain stable and allow healing [20, 21]. If there is a failure in stability, it is necessary to correct it with a new osteosynthesis or the use of immobilization [22].

The physician must be careful to direct the waves in such a way that there is no metallic plate between the generator and the bone, which can prevent the progression of energy, preventing its action on the bone to be treated.

There is still a lack of standardization of the treatment regarding the number of sessions and energy used for each type of non-unions. This makes it difficult to compare the published studies. However, most authors use the same dosage of energy and number of shocks in all types of bones, with an average of 3000 shock waves being applied to each session, ranging from one to three sessions [5, 23].

Treatment with the most intense and deep focused waves is usually done under anesthesia and can be repeated after 4–6

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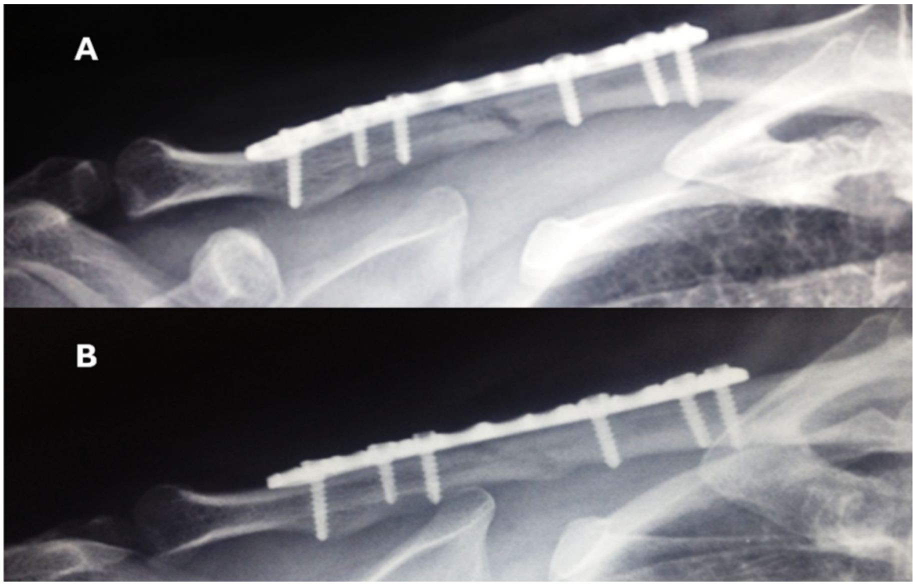

Figure 1: Case 1: Female 46 years old. A: 8 months after osteosynthesis of right clavicle fracture with union failure. B: 6 months after radial pressure waves applications.

weeks from the first stimulus, with most patients receiving two to three sessions. The energy used ranges from 0.18 to 0.30 mJ/mm2. The best results are reached using electro-hydraulic and electro-magnetic generators. Focused shock wave treatment has importante support in the literature, it is safe and effective, with several articles proving good results being the best treatment method when using mechanical waves to treat non-unions [24-26].

When using radial waves, anesthesia is not necessary and at least three sessions are performed with at an intervals of one week, applying 3000 waves in each session directly to the focus of the non-union with a level of energy between 0.18 to and 0.20 mJ/mm2. The use of radial waves is indicated only for superficial bones (Figs. 1-3) and still lacks scientific proof [27].

The best results are reported with the use of focused shock waves devices with hydraulic and magnetic generators, using fluoroscopy to locating the exact point of treatment. A success rate between with 65 to and 78% has been reported [24-28]. Good results are observed in both hypertrophic and atrophic non-unions. Immobilization after treatment for 6–8 weeks may be necessary in cases of focus instability [23, 24].

Most of the studies comprise case series, but there are also studies comparing focused shock waves with traditional surgery on the femur, scaphoid, and metatarsal. These studies demonstrate similar results to those of surgical treatment, but with much lower cost, morbidity, and complications [28-31].

There are simple reviews and systematic reviews of the literature confirming the effectiveness of the use of focused shock waves, but more controlled studies should be conducted to compare shock waves to placebo and other techniques. [32-35].

Pain at the time of application that may require the use of general anesthesia or regional block. Adverse effects are edema, petechiae, superficial hematoma, and pain in the 1st day after application with good evolution with medical follow-up. There are no reports of serious complications with treatment [34,35].

The use of radial waves for specific cases of non-unions in superficial bones is supported by the literature, both in vitro and animal experiments, and in retrospective and prospective studies [11, 35-40].

It is an exclusively orthopedic medical treatment because it requires an accurate diagnosis, knowledge of bone pathology, knowledge of regional anatomy avoiding vessels and nerves, and evaluation of healing. Shock waves are safe, and effective, with a

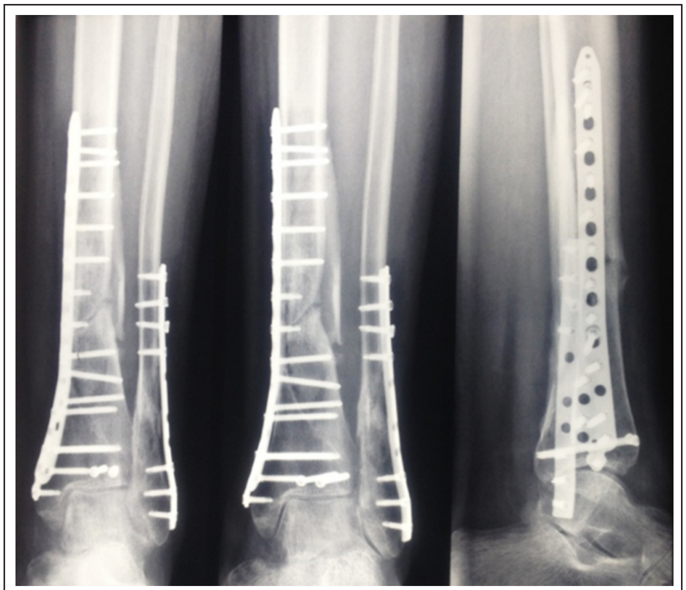

Figure 2: Case 2: Male 59 years old. 9 months of osteosynthesis of tibia and fibula fractures.

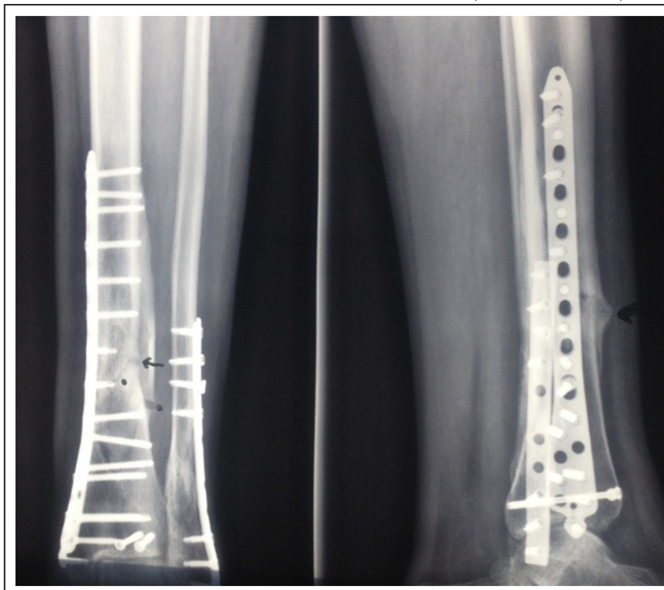

Figure 3: Case 2, 6 months after radial pressure waves applications.

lower cost than surgery in Brazil; they are performed throughout the national territory. It is a treatment recognized by the Federal Council of medicine Medicine and the Brazilian Society of Orthopedics.

After 20 years of clinical practice, published studies, and extensive support in the literature, we are sure that this treatment is an option for cases of bone healing failures.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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References

1. Bell A, Templeman D, Weinlein JC. Nonunion of the femur and Tibia: An update. Orthop Clin North Am 2016;47:365-75.

2. Ekegren CL, Edwards ER, de Steiger R, Gabbe BJ. Incidence, Costs and Predictors of Non-Union, Delayed Union and Mal-Union Following Long Bone Fracture. Int J Environ Res Public Health. 2018 Dec 13;15(12):2845. doi: 10.3390/ijerph15122845. PMID: 30551632; PMCID: PMC6313538.

3. Rupp M, Biehl C, Budak M, Thormann U, Heiss C, Alt V. Diaphyseal long bone nonunions - Types, aetiology, economics, and treatment recommendations. Int Orthop 2017;42:247-58.

4.Schaden W, Mittermayr R, Haffner N, Smolen D, Gerdesmeyer L, Wang CJ. Extracorporeal shockwave therapy (ESWT)--First choice treatment of fracture non-unions? Int J Surg 2015;24:179-83.

5.Wang CJ, Chen HS, Chen CE, Yang KD. Treatment of nonunions of long bone fractures with shock waves. Clin Orthop Relat Res 2001;387:95-101.

6. Haupt G, Haupt A, Gerety B, Chvapil M. Enhancement of fracture healing with extracorporeal shock waves. J Urol 1990;158:4.

7. Valchanou VD, Michailov P. High energy shock waves in the treatment of delayed and nonunion of fractures. Int Orthop. 1991;15(3):181-4. doi: 10.1007/BF00192289. PMID: 1743828.

8. Main G, Haupt A, Ekkernkamp A, Gerety B, Chvapil M. Influence of shock waves on fracture healing. Urology 1992;39:529-32.

9. Kertzman P, Lenza M, Pedrinelli A, Ejnisman B. Shockwave treatment for musculoskeletal diseases and bone consolidation: Qualitative analysis of the literature. Rev Bras Ortop 2015;50:3-8.

10. Cheng JH, Wang CJ. Biological mechanism of shockwave in bone. Int J Surg. 2015 Dec;24(Pt B):143-6. doi: 10.1016/j.ijsu.2015.06.059. Epub 2015 Jun 25. PMID: 26118613.

11. Schnurrer-Luke-Vrbanić T, Avancini-Dobrović V, Sosa I, Cvijanovic O, Bobinac D. Effect of radial shock wave therapy on long bone fracture repair. J Biol Regul Homeost Agents. 2018 Jul-Aug;32(4):875-879. PMID: 30043570.

12. d'Agostino MC, Craig K, Tibalt E, Respizzi S. Shock wave as biological therapeutic tool: From mechanical stimulation to recovery and healing, through mechanotransduction. Int J Surg. 2015 Dec;24(Pt B):147-53. doi: 10.1016/j.ijsu.2015.11.030. Epub 2015 Nov 28. PMID: 26612525.

13. Wang CJ, Wang FS, Yang KD. Biological effects of extracorporeal shockwave in bone healing: a study in rabbits. Arch Orthop Trauma Surg. 2008 Aug;128(8):879-84. doi: 10.1007/s00402-008-0663-1. Epub 2008 Jun 17. PMID: 18560855.

14. Ha CH, Kim S, Chung J, An SH, Kwon K. Extracorporeal shock wave stimulates expression of the angiogenic genes via mechanosensory complex in endothelial cells: mimetic effect of fluid shear stress in endothelial cells. Int J Cardiol. 2013 Oct 9;168(4):4168-77. doi: 10.1016/j.ijcard.2013.07.112. Epub 2013 Aug 1. PMID: 23915523.

15. Xu JK, Chen HJ, Li XD, Huang ZL, Xu H, Yang HL, Hu J. Optimal intensity shock wave promotes the adhesion and migration of rat osteoblasts via integrin β1-mediated expression of phosphorylated focal adhesion kinase. J Biol Chem. 2012 Jul 27;287(31):26200-12. doi: 10.1074/jbc.M112.349811. Epub 2012 May 31. PMID: 22654119; PMCID: PMC3406705.

16. Sun D, Junger WG, Yuan C, Zhang W, Bao Y, Qin D, Wang C, Tan L, Qi B, Zhu D, Zhang X, Yu T. Shockwaves induce osteogenic differentiation of human mesenchymal stem cells through ATP release and activation of P2X7 receptors. Stem Cells. 2013 Jun;31(6):1170-80. doi: 10.1002/stem.1356. PMID: 23404811; PMCID: PMC4243484.

17. Wang FS, Wang CJ, Chen YJ, Chang PR, Huang YT, Sun YC, et al. Ras induction of superoxide activates ERK-dependent angiogenic transcription factor HIF-1alpha and VEGF-A expression in shock wave-stimulated osteoblasts. J Biol Chem 2004;279:10331-7.

18. Kusnierczak D, Brocai DR, Vettel U, Loew M. Der Einfluss der extrakorporalen Stosswellenapplikation (ESWA) auf das biologische Verhalten von Knochenzellen in vitro [Effect of extracorporeal shockwave administration on biological behavior of bone cells in vitro]. Z Orthop Ihre Grenzgeb. 2000 Jan-Feb;138(1):29-33. German. doi: 10.1055/s-2000-10109. PMID: 10730360.

19. Császár NB, Angstman NB, Milz S, Sprecher CM, Kobel P, Farhat M, Furia JP, Schmitz C. Radial Shock Wave Devices Generate Cavitation. PLoS One. 2015 Oct 28;10(10):e0140541. doi: 10.1371/journal.pone.0140541. PMID: 26509573; PMCID: PMC4625004.

20. Xu ZH, Jiang Q, Chen DY, Xiong J, Shi DQ, Yuan T, Zhu XL. Extracorporeal shock wave treatment in nonunions of long bone fractures. Int Orthop. 2009 Jun;33(3):789-93. doi: 10.1007/s00264-008-0553-8. Epub 2008 Apr 25. PMID: 18437381; PMCID: PMC2903117.

21. Bara T, Synder M. Nine-years experience with the use of shock waves for treatment of bone union disturbances. Ortop Traumatol Rehabil. 2007 May-Jun;9(3):254-8. English, Polish.

PMID: 17721422.

22. Rompe JD, Rosendahl T, Schöllner C, Theis C. High-energy extracorporeal shock wave treatment of nonunions. Clin Orthop Relat Res. 2001 Jun;(387):102-11. doi: 10.1097/00003086-200106000-00014. PMID: 11400870.

23. Schaden W, Fischer A, Sailler A. Extracorporeal shock wave therapy of nonunion or delayed osseous union. Clin Orthop Relat Res 2001;387:90-4.

24. Vulpiani MC, Vetrano M, Conforti F, Minutolo L, Trischitta D, Furia JP, Ferretti A. Effects of extracorporeal shock wave therapy on fracture nonunions. Am J Orthop (Belle Mead NJ). 2012 Sep;41(9):E122-7. PMID: 23365814.

25. Kuo SJ, Su IC, Wang CJ, Ko JY. Extracorporeal shockwave therapy (ESWT) in the treatment of atrophic non-unions of femoral shaft fractures. Int J Surg. 2015 Dec;24(Pt B):131-4. doi: 10.1016/j.ijsu.2015.06.075. Epub 2015 Jul 9. PMID: 26166737.

26. Moya D, Ramón S, Schaden W, Wang CJ, Guiloff L, Cheng JH. The Role of Extracorporeal Shockwave Treatment in Musculoskeletal Disorders. J Bone Joint Surg Am. 2018 Feb 7;100(3):251-263. doi: 10.2106/JBJS.17.00661. PMID: 29406349.

27. Kertzman P, Császár NB, Furia JP, Schmitz C. Radial extracorporeal shock wave therapy is efficient and safe in the treatment of fracture nonunions of superficial bones: A retrospective case series. J Orthop Surg Res 2017;12:164.

28. Cacchio A, Giordano L, Colafarina O, Rompe JD, Tavernese E, Ioppolo F, et al. Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone nonunions. J Bone Joint Surg Am 2009;91:2589-97.

29. Furia JP, Juliano PJ, Wade AM, Schaden W, Mittermayr R. Shock wave therapy compared with intramedullary screw fixation for nonunion of proximal fifth metatarsal metaphyseal-diaphyseal fractures. J Bone Joint Surg Am 2010;92:846-54.

30. Quadlbauer S, Pezzei C, Beer T, Jurkowitsch J, Keuchel T, Schlintner C, Schaden W, Hausner T, Leixnering M. Treatment of scaphoid waist nonunion by one, two headless compression screws or plate with or without additional extracorporeal shockwave therapy. Arch Orthop Trauma Surg. 2019 Feb;139(2):281-293. doi: 10.1007/s00402-018-3087-6. Epub 2018 Dec 6. PMID: 30523445.

31. Notarnicola A, Moretti L, Tafuri S, Gigliotti S, Russo S, Musci L, Moretti B. Extracorporeal shockwaves versus surgery in the treatment of pseudoarthrosis of the carpal scaphoid. Ultrasound Med Biol. 2010 Aug;36(8):1306-13. doi: 10.1016/j.ultrasmedbio.2010.05.004. PMID: 20691920.

32. Schmitz C, Császár NB, Milz S, Schieker M, Maffulli N, Rompe JD, Furia JP. Efficacy and safety of extracorporeal shock wave therapy for orthopedic conditions: a systematic review on studies listed in the PEDro database. Br Med Bull. 2015;116(1):115-38. doi: 10.1093/bmb/ldv047. Epub 2015 Nov 18. PMID: 26585999; PMCID: PMC4674007.

33. Birnbaum K, Wirtz DC, Siebert CH, Heller KD. Use of extracorporeal shock-wave therapy (ESWT) in the treatment of non-unions. A review of the literature. Arch Orthop Trauma Surg. 2002 Jul;122(6):324-30. doi: 10.1007/s00402-001-0365-4. Epub 2002 Mar 12. PMID: 12136295.

34. Petrisor B, Lisson S, Sprague S. Extracorporeal shockwave therapy: A systematic review of its use in fracture management. Indian J Orthop. 2009 Apr;43(2):161-7. doi: 10.4103/0019-5413.50851. PMID: 19838365; PMCID: PMC2762266.

35. Willems A, van der Jagt OP, Meuffels DE. Extracorporeal Shock Wave Treatment for Delayed Union and Nonunion Fractures: A Systematic Review. J Orthop Trauma. 2019 Feb;33(2):97-103. doi: 10.1097/BOT.0000000000001361. PMID: 30570614.

36. Schnurrer-Luke-Vrbanic T, Avancini-Dobrovic V, Sosa I, Cvijanovic O, Bobinac D. VEGF-A expression in soft tissues repaired by shockwave therapy: differences between modalities. J Biol Regul Homeost Agents. 2018 May-Jun;32(3):583-588. PMID: 29921384.

37. Gollwitzer H, Gloeck T, Roessner M, Langer R, Horn C, Gerdesmeyer L, et al. Radial extracorporeal shock wave therapy (rESWT) induces new bone formation in vivo: Results of an animal study in rabbits. Ultrasound Med Biol 2013;39:126-33.

38. Diaz-Rodriguez L, Garcia-Marinez O, Arroyo-Morales M, Ramos-Torrecillas J, De Luna-Bertos E, Ruiz C. Effect of radial extracorporeal shock wave therapy on proliferation, cell viability and phagocytosis of human osteoblasts (Mg63). Adv Sci Lett 2012;17:325-9.

39. Silk ZM, Alhuwaila RS, Calder JD. Low-energy extracorporeal shock wave therapy to treat lesser metatarsal fracture nonunion: Case report. Foot Ankle Int 2012;33:1128-32.

40. Kertzman PF, Fucs PM. Does radial shock wave therapy works in pseudarthrosis? Prospective analysis of forty four patients. Int Orthop 2021;45:43-9.

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