Piezoelectric Shock Wave Sources: Are they Still the Cinderella to Treat Musculoskeletal Disorders?

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Abstract

There are three types of focused shock wave generators: electrohydraulic, electromagnetic and piezoelectric. Although it has been postulated that there are no differences in clinical efficacy between the three, the information available on the results of the use of piezoelectric generators to treat musculoskeletal disorders is very limited.

The objective of this publication is to demonstrate the little existing evidence on the use of piezoelectric system in some areas of ESWT and to to highlight their versatility and promising future.

Keywords: Musculoskeletal disorders, Shock waves, ESWT, Piezoelectric

Introduction

One of the meanings that the Collins English Dictionary describes for the word "Cinderella" is "person or organization that receives very little attention and that deserves to receive more" [1].

It is well known that there are three types of shock wave sources used in extracorporeal shock wave therapy (ESWT): Electrohydraulic, electromagnetic, and piezoelectric [2-4]. To treat musculoskeletal disorders, thus far, there is no evidence that a certain shock wave generation principle is superior to another [5]. Treatment outcomes depend on several factors, such as the pressure profile, the energy density, the size of the focal region, the number of sessions, and the applied pulses. So why compare piezoelectric sources to Cinderella? We believe that the treatment of muscles, bones, and joints injuries with this technology is not widely disseminated in the medical literature.

The main goal of this analysis is to reveal the low number of published studies reporting the use of piezoelectric devices in comparison with electrohydraulic and electromagnetic generators for the treatment of musculoskeletal pathologies and to highlight the versatility of piezoelectric shock wave sources and their promising future.

Piezoelectric technology in scientific publications dealing with ESWT

A simple analysis of different sources of research, clinical results, and education demonstrates why we believe that this technology has not been sufficiently discussed.

Performing a PubMed [6] search including the terms "shockwaves" and "shock waves" combined with "non-union," we found that out of 67 studies, only one [7] reported the use of shock waves generated with a piezoelectric device to treat bone fractures. The same search was carried out in relation to the treatment of calcifications. In this case, only two out of 67 studies were performed with a piezoelectric shock wave generator [8, 9].

When correlating the search with the treatment of tendinopathies, only two studies resulted out of a total of 186. Both papers were related to the use of piezoelectrically generated shock waves in patellar tendinopathies. In both cases, the authors reported no significant improvements with the use of this technology [10, 11].

Furthermore, we performed the same search in PEDro [12] and found only one study on the use of piezoelectric focused shock wave generation to treat plantar fasciopathy [13].

The use of piezoelectric technology in reviews and meta-analyses was also examined. In an important systematic review published by Bannuru et al. in 2014 [14] on the use of ESWT to treat chronic calcific tendinitis of the shoulder, no studies performed with piezoelectric systems were found (Table 1).

In a recent review that compares the scientific evidence on operative versus non-operative management of calcific tendinopathies of the rotator cuff by Bechay et al. [15], the authors cited only studies performed with electrohydraulic and electromagnetic generators.

A literature review published by Thiele et al. [16] on ESWT to treat lateral epicondylitis found evidence only regarding the use of radial pressure waves and shock waves emitted by electrohydraulic and electromagnetic systems (Table 2).

As shown in Table 3, a recent systematic review and meta-analysis published by Sansone et al. [17] revealed that none of the clinical studies included the use of piezoelectric generators to treat non-union in long bones.

Finally, we evaluated the abstracts of the 30 studies presented at the 23rd World Congress

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Submitted Date: 15 Jul 2022, Review Date: 03 Aug 2022, Accepted Date: 23 Sept 2022 & Published: 10 Dec 2022

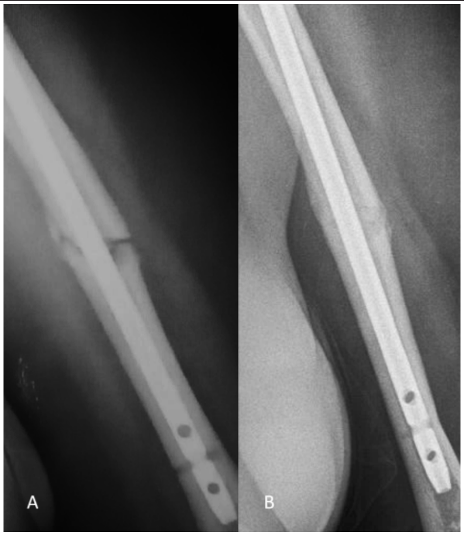

Figure 1: (a) Left humerus fracture of 6 months of evolution without radiological signs of healing. (b) Results after two sessions of high energy (0.55 mJ/mm^2) 6000 pulses with a frequency of 6 Hertz.

Table 1: Devices used to treat chronic calcific tendinitis of the shoulder. (Bannuru et al. in 2014 [14]).

Author	Device	Author	Device
Loew (1995)	electrohydraulic	Pleiner (2004)	electrohydraulic
Rompe (1998)	electromagnetic	Krasny (2005)	electromagnetic
Loew (1999)	electrohydraulic	Sabeti (2005)	electromagnetic
Rompe (2001)	electromagnetic	Cacchio (2006)	radial
Wang (2001)	electrohydraulic	Albert (2007)	electromagnetic
Daecke (2002)	electromagnetic	Sabeti (2007)	electromagnetic
Haake (2002)	electromagnetic	Hsu (2008)	electrohydraulic
Gerdesmeyer (2003)	?????	Hearnden (2009)	????
Cosentino (2003)	electrohydraulic	Farr (2011)	electromagnetic
Perlick (2003)	electromagnetic	Tornese (2011)	electromagnetic
Pan (2004)	electrohydraulic	Ioppolo (2012)	electromagnetic
Peters (2004)	electromagnetic		

of the International Society for Medical Shockwave Treatment [18]. Unfortunately, the type of generator used was mentioned only in 11 abstracts (Table 4). None of the identified devices was piezoelectric.

Discussion

A quick search in the literature and a recent world meeting on ESWT showed a low use of piezoelectric technology to treat musculoskeletal disorders. This is surprising because the technology is not new and has been successful in other clinical applications. Piezoelectric shock wave sources were developed in 1978 by the company Richard Wolf GmbH (Knittlingen, Germany) [2]. They produced shock waves by a high-voltage discharge across an arrangement of piezoelectric elements mounted on the inner surface of a spherical backing placed inside a fluid-filled cavity. Each element generates a pressure pulse that propagates toward the center, or focal region, producing a shock wave due to superposition and nonlinear distortion [2]. At present, there are different types of piezoelectric generators. The shape, arrangement, and quantity of the piezoelectric elements vary depending on their specific application.

In 1989, the first treatment of a case of salivary gland lithiasis was carried out with a piezoelectric shock wave source [2]. Piezoelectric devices have several advantages, such as a very long lifespan, as well as low levels of noise and electromagnetic radiation. In the past, the small size of their focal region was considered a disadvantage for some clinical applications; however, the possibility of designing focal zones that are not only determined by the geometrical parameters of the source allowed the design of devices having focal zones for specific clinical applications. The development of sources with two layers of piezoelectric elements, as well as planar and linear arrangements increased their versatility [2].

The efficacy of piezoelectric shock wave generators in the treatment of calculi of the salivary glands [19], kidney stones [20], and in the gallbladder [21] is well known.

Table 2: Devices used to treat lateral epicondylitis (Thiele et al. [16])

Author	Device	Author	Device
Rompe (1996)	electromagnetic	Lebrun (2005)	electromagnetic
Crowther (2002)	electromagnetic	Pettrone (2005)	electrohydraulic
Haake (2002)	electromagnetic	Spacca (2005)	radial
Speed (2002)	electromagnetic	Radwan (2007)	electrohydraulic
Melikyan (2003)	electromagnetic	Staples (2008)	electromagnetic
Mehra (2003)	radial	Özturan (2010)	electrohydraulic
Chung (2004)	electromagnetic	Gündüz (2012)	radial
Rompe (2004)	electromagnetic	Lee (2012)	radial
Levitt (2004)	electrohydraulic		

Table 3: Devices used to treat nonunion in long bones (Sansone et al. [17])

Author	Device	Author	Device
Valchanou (1991)	electrohydraulic	Furia (2010)	electrohydraulic
Vogel (1997)	electromagnetic	Elster (2010)	electrohydraulic
Wang (2001)	electrohydraulic	Stojadinovic (2011)	electrohydraulic
Schaden (2001)	electrohydraulic	Alvarez (2011)	electrohydraulic
Rompe (2001)	electromagnetic	Czarnowska (2013)	electrohydraulic
Biedermann (2003)	electrohydraulic	Kuo (2015)	electrohydraulic
Chooi (2004)	electrohydraulic	Alkhawashki (2015)	electrohydraulic
Wang (2007)	electrohydraulic	Zhai (2016)	electrohydraulic
Xu (2009)	electrohydraulic	Haffner (2016)	electrohydraulic
Cacchio (2009)	electromagnetic	Sandoval (2017)	electromagnetic
Moretti (2009)	electromagnetic	Kertzman (2017)	radial

Table 4: Abstracts of the 30 studies presented at the 23rd World Congress of the International Society for Medical Shockwave Treatment [18]

Author	Device	Author	Device	Author	Device
Ko	Electrohydraulic	Tognolo	????	Freitag	????
Omodani	????	Di Luise	????	Holfeld	????
Sugiyama	Electromagnetic	Nedelka	Radial	Wu	????
Heinzel	Electrohydraulic	Kouloulas	????	Koolen	Electrohydraulic
Cheng	????	Markina	????	Russo	Electromagnetic
Freitag	Electrohydraulic	Motil	????	Sun	????
Nägele	????	Chuang	????	Santoboni	????
Pölzl	????	S-Salinas	radial	Odagiri	????
Tepeköylü	????	Goldstein	Electrohydraulic	Moya	Electrohydraulic
Graber	????	Joos	Electrohydraulic	Mittermayr	????

Furthermore, Muller-Ehrenberg and Licht [22] treated 30 patients with myofascial pain syndrome, demonstrating not only the therapeutic effectiveness but also the diagnostic utility of piezoelectrically generated waves.

Recently, piezoelectric-generated focused shock waves have shown effectiveness in the treatment of rotator cuff calcifications. Moya et al. reported a retrospective series of 23 calcific tendinopathies of the rotator cuff treated with a piezoelectric single-crystal device [9]. Complete resorption of the calcification was reached in 82.6% of the cases, and partial disappearance of the calcification was achieved in 8.7%.

Good results have also been reported with the use of piezoelectrically generated waves in pseudarthrosis of small bones (Fig. 1). Broegaard [23] reported a small series of treatments including different bone pathologies with good results. More than 10 years ago, Albisetti et al. [7] published 19 cases of trainee ballet dancers from La Scala in Milan with stress fractures in the base of the metatarsal bones treated with focused shock waves emitted by a piezoelectric source. The authors reported that ESWT allowed dancers to return to practice an average of 4.6 weeks after the first application. At the 2.2-year mean follow-up (range 1.3–3.3 years), all dancers were found to be healed without pain.

Recently, the possibility of obtaining good results in dental bone pathology has also been reported [24]. In a series of 16 patients with three types of pathologies: (1) Sequelae of periodontal disease treatment, (2) peri-implant fibrosis with minimal dental-implant mobility, and (3) poor nutrition in the area to be grafted, 12 patients (75%) had favorable clinical and imaging changes after shock wave treatment.

Conclusion

Even if there are still very few articles reporting the use of piezoelectric shock wave sources to treat musculoskeletal pathology, there is evidence that the technique has great potential. Another meaning of "Cinderella" is "a woman who achieves fame after being obscure" [1]. It seems that this will be the case for piezoelectric technology in the treatment of musculoskeletal disorders.

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.

Conflicts of Interest: Nil. **Source of Support:** None.

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Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Moya D, Loske AM | Piezoelectric Shock Wave Sources: Are they Still the Cinderella to Treat Musculoskeletal Disorders? | Journal of Regenerative Science | July - December 2022; 2(2):03-06.