Application of Local Vibrations in Delayed and Non-Union Fractures: a Case Study

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The aim of the study was to assess the efficacy of local vibration treatments (LV) in delayed-union and non-union fractures, through therapeutic exercise vibration (TEV) practice, analysing the radiological trend. The Medical Engineering Service of the Fondazione Policlinico Tor Vergata in collaboration with the Chair-Department of Rehabilitation Medicine of the University of Rome Tor Vergata and the Boscosystem company, is developing a device dedicated to LV application, to favour bone regeneration and muscle strengthening. This case report analyses the bone activity of a male patient presenting a right tibial fracture, treated with TEV. At the end of the TEV program, clinical results confirmed independent ambulation with disappearance of perimalleolar edema, while radiographic images revealed the presence of bone repair activity around the fracture line.

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I. INTRODUCTION

In recent years, therapeutic application of vibration energy in Physical and Rehabilitation Medicine (PRM) has been established for the treatment of specific clinical pathologies and for rehabilitation. The results of a meta-analysis study of International Publications in PubMed, not only show an increasing number of publications on vibration energy but mostly of those regarding PRM (see Fig.1):

| Keywords          | Publications               |
|-------------------|----------------------------|
| Vibration         | 20176 articles from        |
|                   | 1881 to 2008               |
| Vibration energy  | 1493 articles from         |
|                   | 1883 to 2008               |
| Whole Body Vibration | 645 articles from 1989   |
|                   | to 2008                    |
| Vibration and     | 664 articles from 1969     |
| Rehabilitation    | to 2008                    |

Many scientific studies argue that vibrations induce together metabolic and mechanical adaptive responses of the human body. Indeed mechanical factors hold an important role in human adaptive response, as they improve muscular functions and increase bone regeneration process by stimulating the muscle and triggering osteoblasts. Therefore, vibration are shown to be a powerful activation stimulus for the whole neuromuscular and skeletal system. In view of the evidence on the effectiveness of vibration energy on tissues and systems, mostly on the hormonal, neuromuscular and muscular systems, on the bone tissue and on the peripheral blood circulation, a therapeutic treatment that uses as stimulus vibration energy has been implemented.

As every treatment in PRM, the application of vibratory energy aims to improve the quality of life of the patient. It may be implemented either as a therapeutic exercise as well as a physical mean applied directly on the body surface. Mechanisms for implementing vibration hold a critical role in the adaptive response of the body. While in the case of treatments which require a systemic response, the most appropriate solution appears to be whole body vibration (WBV), in specific and local applications, lim-
FIG. 1: Publications on Vibration and Rehabilitation

aped to a particular body segment, the optimum is achieved with local vibration (LV) (Figure 2).
This is due to the fact that our body is a system with n-degrees of freedom, where every segment has its own resonance frequency. Therefore regarding their own resonance frequency there can be an amplification or attenuation of the vibrations applied, hence, vibration can have positive or negative effects on the body depending on time, frequency and level of exposure.

FIG. 2: Application of (a) WBV, (b) upper arm vibrations, UAV, (c) LV on the cutaneous projection of the structure to be treated.

In specific diseases, there is a clinical need to focus the effects of the treatment, to:

- strengthen the muscle after peripheral nervous system lesions or myo-osteo-articular lesions;
- reinforce muscle and minimize muscle hypotrophy after orthopaedic surgery;
- improve muscle distensibility in joint recovery, in posture changes caused by retraction myo-tendon and in muscle lesions;
- increase bone remineralisation process by triggering osteoblasts;
- amplify the proprioceptive afferents in balance alterations and proprioceptive recovery after orthopaedic lesions.

As a result to avoid negative effects and focus the treatment for clinical needs, the best solution is gained applying LV. In this study the attention was focused on the application of LV in bone fractures, in order to incite bone regeneration and remineralisation activity. The aim of the study was to assess the efficacy of local vibration treatments in delayed-union and non-union fractures, through a therapeutic exercise vibration (TEV) practice, by analysing the radiological trend. Inadequate response to fracture injury can occur resulting in delayed-union or non-union. Non-union by definition is present when cessation of all reparative processes of healing has occurred without bone union; while delayed-union is the prolongation of time to fracture union. Differentiation between delayed union and non union is based on radiographic criteria and time. The failure to show any progressive change in the radiographic appearance after the period of time during which normal fracture union would be thought to have occurred is evidence of non-union. The changes in radiographic appearance may be slight and therefore radiographs should be scrutinized monthly to see if changes have occurred.

II. MATERIAL AND METHODS

In order to apply LV, the Medical Engineering Service and the Dept. of Physical and Rehabilitation Medicine at the Tor Vergata University, are developing a device dedicated to LV application for bone regeneration and muscle strengthening. This device was used in this case study (Boscosystem, 2008) (Figure 3). Mechanical vibrations are caused by the action of forces that vary over time. In this device the centripetal force is generated by an unbalanced mass, housed within a handpiece designed part that transmits the vibrations to the area of interest by means of specific adapters and protects the operator by limiting their absorption. Moreover, the command console that controls the rotation of the mass is designed to allow the operator to regulate the specific parameters for TEV, such as time and frequency. The device delivers mechanical vibrations within a frequency range of 20-50Hz. Vibrations within this specific range
induce positive effects, causing a stimulation of bone regeneration and an increase in muscle dis-
tensibility and strength.

FIG. 3: Device dedicate to LV application.

The TEV application was based on a four week training scheme with five weekly treatments or-
organised as follow:

- daily treatments of 6 sets, 5 repetition each;
- each repetition at 35 Hz for 30 seconds;
- 60 seconds pause between repetition;
- 90 seconds pause between sets;
- application on heel.

FIG. 4: TEV application on heel.

For the evaluation of the treatment and assessment of the efficacy of LV in non-union frac-
tures, three radiographs were performed at different times: one in admission, one at discharge that is at the end of treatment and one at 60 days from the end of the treatment as a fol-
low up. Clinical and radiological aspects are in-
tegrated by the administration of rating scales for pain (Mc Gill Pain questionnaire) and func-
tional evaluation (Barthel Index and LEFS - Lower Extremity Functional Scale).

III. RESULTS

Since the early vibration applications, the patient expressed improvements in paresthetic symptomatology and also a reduction of perile-
sion edema was shown (tab.1-2). The results of the Cirtometer show a difference of 1cm around the malleolus and at 10cm above the medial malleolus indicating a reduction of the perileision edema, while the LEFS Scale and the Barthel Index show respectively an increase from 31/80 to 46/80 and from 98/100 to 100/100 before and after treatment. Furthermore, algic symptomat-
ology, after a small increase in the early phase, clearly improved during the treatments (tab.2). Algic symptomatoly decreased as shown by the McGill Pain Questionnaire results from 25/60 before treatment to 10/60 after treatment.

| Cirtometer AAH | Entrance (cm) | Discharge (cm) |
|---------------|---------------|----------------|
| R leg         | L leg         | R leg          | L leg          |
| Peri-malleolar| 29.5          | 27             | 28.5           | 27             |
| 5cm over medial malleolus | 28.5   | 24             | 28             | 24             |
| 10cm over medial malleolus | 29.5   | 25.5           | 28.5           | 25.5           |

FIG. 5: Reduction in Cirtometer at entrance and discharge.

| Rating Scales     | Entrance | Discharge |
|-------------------|----------|-----------|
| LEFS              | 31/80    | 46/80     |
| Barthel Index     | 98/100   | 100/100   |
| Mc Gill Pain Questionnaire | 25/60 | 10/60 |

FIG. 6: Rating Scales results at entrance and discharge.
At the end of the TEV program, clinical results confirmed independent ambulation with disappearance of perimalleolar edema, while radiographic images revealed the presence of bone repair activity around the fracture line in both lateral and anterior view (Figs. 7 and 8).

FIG. 7: Radiographic images lateral view: entrance 23/09/08, discharge 30/10/08, follow up 16/01/09.

FIG. 8: Radiographic images anterior view: entrance 23/09/08, discharge 30/10/08, follow up 16/01/09.

IV. DISCUSSION

This case study analyses the bone activity of a male patient presenting a right tibial fracture with a non-union diagnosis, treated with TEV. Results confirmed an improvement in paresthetic and functional symptomatology and resolution of perilesion edema. If in the case of perilesional edema the physiological reasons behind this improvement is quite clear, given the known effects of vibration on blood circulation, as regards to the paresthetic and aligic component we can hypothesize that the large number of forces and impacts induced by the vibration produced a local desensitization. Pain in fact after an initial increase presented a rapid disappearance, particularly in the final phase. To analyze the effectiveness of the application of local mechanical vibrations to the specific case study an evaluation of the fractured limb was conducted from the radiological point of view at entrance, at the end of treatment and after 60 days from the end. The radiographic image performed at entrance (23/09/09) shows some of the characteristic radiological features of non union fractures: presence of bone heads remodelling, partial obliteration of the medullar canal and a typical hypertrophic appearance with external bone proliferation. The radiographic image taken at discharge (30/10/08) shows specially in the lateral view, the presence of a higher bone density formation at fracture line expression of biological activity in progress. Radiographic image at follow up, 60 days after the end of treatment (16/01/09), shows an increase of the bone density formation already highlighted at discharge, reflecting persistence of biological activity, with appearance of osteoreparative event at fracture line. The results reported in the clinical study, confirm that therapeutic exercise vibration associated with normal rehabilitation treatments, is a great contribution in the treatment of pathological disorders of bone regeneration, by resolving delayed union consolidation or greatly reducing the time of recovery.

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