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Evaluation of Low-Level Laser Therapy with Diode Laser for the Enhancement of the Orthodontic Tooth Movement: a Split-Mouth Study

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Abstract: This study evaluated the effect of low-level laser irradiation induces by diode laser on the speed of orthodontic tooth movement of canines submitted to initial retraction. Twenty-four mandibular canines were retracted by using NiTi spring (force of 150 g/side). Thirteen of those were irradiated with a diode laser 980-nm diode laser (Wiser Laser Doctor Smile, Lambda) operating at an 810-nm wavelength (1 W of output power, continuous wave of 66.7 J/cm²) that was equipped with a 0.6-mm optical fiber in continuous-wave mode. The canine retraction was accomplished by using prefabricated coil springs. The right of the mandible was chosen to be irradiated with the laser, whereas the left side was considered the control without laser irradiation. The laser was applied with 0-, 3-, 7-, and 14-day intervals. The amount of canine retraction was measured with a digital electronic caliper while the pain level was prompted by a patient questionnaire. The speed of tooth movement was significantly greater in the laser group than in the control group. The pain intensity was also at a lower level in the laser group. Our findings suggest that diode laser therapy can highly accelerate tooth movement during orthodontic treatment and can also effectively reduce pain level.

Keywords: Low level laser therapy, Diode laser, Orthodontic tooth movement, Pain, Split-mouth clinical trial

1. Introduction

The orthodontic movement is divided into three elements of tooth displacement: initial strain, lag phase, and progressive tooth movement. An initial strain of 0.4 to 0.9 mm occurs within about one week because of periodontal ligament displacement, bone strain, and extrusion [1,2]. Initial tooth displacement occurs within seconds, and this leads to a buildup of stresses within the periodontal ligament, which is supposed to be a critical rate-limiting step for the osteogenic response responsible for bone remodelling [3,4].

Overall, long-term treatment is one of the main reasons for patients to refrain from treatment [5,6]. It also has other disadvantages such as increasing the amount of decay, gingivitis and root

resorption [7-9]. Thus, a non-invasive method of accelerating tooth movement physiologically is needed [5,10]. Low-level laser therapy (LLLT) is a therapy of laser with various photobiomodulation effects, and these potential effects of laser stimulate the velocity of tooth movement and thereby facilitates the tooth movement in orthodontics [11,12].

LLLT, in the orthodontic field, has been demonstrated to be efficient in biomodulation, with inhibitory effects on analgesia and with stimulating action in tissue repair [13,14]. These stimulation effects are due to the capacity of LLL to accelerate metabolic changes and in bone tissue, to promote faster bone resorption and neoformation, both necessary for orthodontically induced tooth movement [15,16].

Tissue-penetrating light can be generated by numerous types of currently available lasers, including He-Ne, Nd: YAG, and diode lasers, which are often used in the dental field. Surface absorption-type CO₂ and Er: YAG laser light is also widely used. Diode laser light is highly penetrant and minimally absorbed by water [17,18]. In addition, diode lasers are inexpensive devices and easy to miniaturize, which has led to the development of a wide range of clinical applications. Laser therapy can aid in repairing the mucosa, controlling pain, and accelerating wound healing through low mechanical stress on the root surfaces and bactericidal and detoxifying effects [15,19].

At high power, diode lasers can be used to perform incision and hemostasis of soft tissue, whereas, at low power, they can be used for periodontal therapy [20,21] and treatment of dentinal hypersensitivity [22].

With diode laser, even if the peak output is set high, it is possible to suppress the average output to a low level and to more efficiently apply the light energy to the tissue without creating thermal effects or thermal damage. Therefore, in the present study, we examined the application of a diode laser (810 nm) on the experimental clinical model of orthodontic tooth movement.

2. Results

All patients completed the study successfully. Table 1 shows the mean velocity of those movements in both diode laser and control groups. The speed of tooth movement was bigger in the diode laser side than in the control side (Figure 1).

Group	Number of analyzed teeth	Mean speed of tooth movement	SD
Diode laser	12	2.122	0.223
Control group	12	1.324	0.208

Table 1: Speed of tooth movement in the analyzed canine of the mandible.

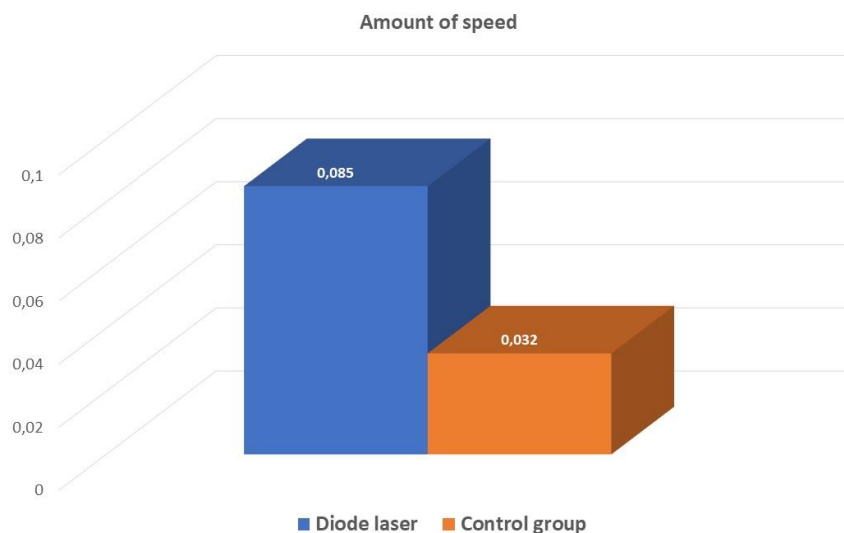


Figure 1: Amount of speed of tooth movement in diode laser and control group. The results are represented as median values.

Figure 2 shows the pain level during different treatment stages of diode laser and control groups, and the Table 4 shows mean rank values for the degree of pain during combined treatment stages. There was a significant difference in the degree of pain between the control and the diode laser side. The degree of pain was higher in the control side at each follow-up session (3, 7 and 14 days after laser activation) (Figure 4). After 6 months, none of the examined teeth presented damage developed in the adjacent periodontal ligament and dental tissues.

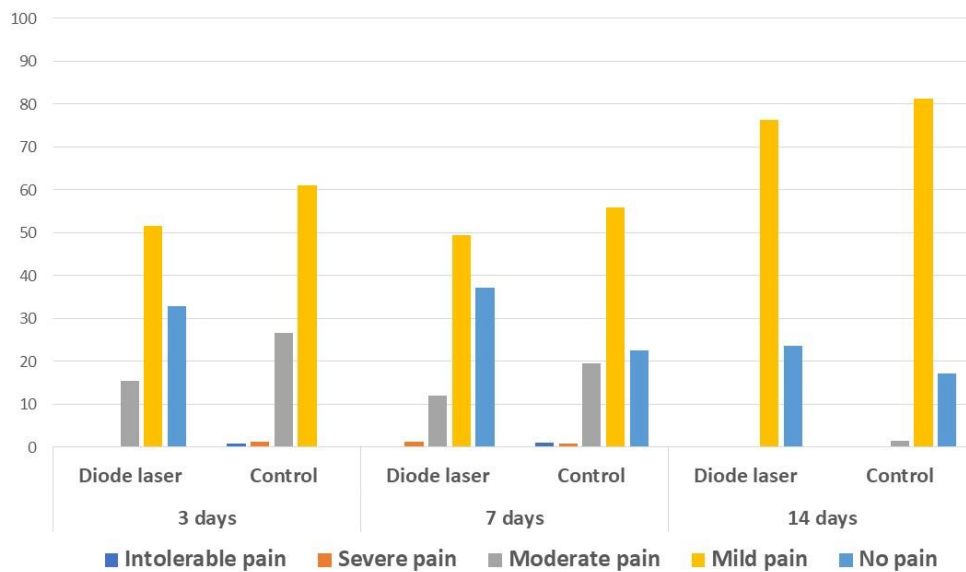


Figure 2: The results of the pain levels experienced in diode laser and control groups at each follow-up session (3, 7 and 14 days). The results are represented as a percentage.

3. Discussion

Few laboratory studies have evaluated the influence of laser on orthodontic movement in animals, but all of them proved that bone tissue that underwent LLL therapy showed an accelerated repair process, increasing bone neoformation and consequently increasing the speed of orthodontic tooth movement [2].

Orthodontic tooth movement involves both modeling and remodeling activities that are modulated by systemic factors such as nutrition, metabolic bone diseases, age, and drug usage history. Biologically active substances, such as cytokines, interleukins (IL-1 β , IL-1RA), and enzymes, are expressed by cells within the periodontium in response to mechanical stress from orthodontic appliances [23-25].

According to several studies, LLLT is an effective tool used to prompt bone repair and modeling post-surgery [26,27]. This has referred to the biostimulation effect of the LLLT. This effect had been well studied in the medical field and proven to have an enhancement effect on fibroblast growth enhancement, wound healing, and bone repair [26].

This enhancement can be the result of osteoblasts proliferation and differentiation and intracellular changes in these cells [28-30]. Saito and Shimizu [31] studied the effects of low-power laser irradiation on bone regeneration in mid palatal suture during expansion in the rat and concluded that one-time or late irradiation (days 4-6) did not affect. However, irradiation during days 0-2 was the most effective.

Biostimulation effects on the bone repair are directly dependent on the dose applied [32-33]. Different parameters have proven to be effective for several different lasers, inducing changes within cell cultures and leading to an increased healing effect, especially in patients with blood disorders [33,34]. Nevertheless, the optimal parameters have yet to be determined [35,36].

Luger et al. [37] used doses of about 64 J/cm² during 14 days, and although this dose could be excessive within the focused area, the authors believe that the scattering reduces the energy level of the laser beams to between 3 and 6% of its original intensity. In our study, the dose at each of the different points around the tooth was higher (66.7 J/cm²) than the dose used by Luger et al. (64 J/cm²), but the distribution of energy into six points surrounding the canine teeth could be more adequate due to a more homogeneous distribution of the energy.

Shimizu et al [38] showed that the orthodontic movement of laser-irradiated rats' teeth was 30% quicker than the nonirradiated rats due to the acceleration of bone formation as a result of the cellular stimulation promoted by LLLT. Our findings are similar to these reports. This ratio could be the biostimulation factor promoted by LLLT. Moreover, we observed that the velocity of tooth movement was bigger on the laser side than in the control side.

Harazaki et al. [39] showed that the low-level laser therapy is an effective tool to manage the post- adjustment orthodontic pain. Our findings in this research confirmed these previous findings; more specifically, the present study showed that during different treatment stages, the pain level of the diode laser group was less in amount than the control group.

In conclusion, the diode laser therapy used in this study was effective for the biostimulation of the periodontal apparatus during orthodontic treatment. The biostimulation determined, in the treated sites, an enhancement in the rate of tooth movement and the reduction of the tooth pain level due to the orthodontic movement.

Further studies are required to explain the mechanisms of laser biostimulation and clinical trials to optimize treatment parameters and discover other effects promoted by LLLT.

4. Materials and Methods

Fourteen patients of both genders (seven females and seven males), with a mean age of 13.1 years (range, 10.5–20.2 years) were selected for this study. The inclusion criteria were as follows: the need for extraction of first premolars due to biprotrusion or dental crowding; the presence of permanent dentition; the absence of any kind of systemic disease; no use any medication; and no previous orthodontic treatment. The local ethical committee of the University of Messina approved the study protocol (prot. 18/18 – 07/03/2018).

Twenty-four mandibular canines were evaluated, 12 lasers irradiated and 12 nonirradiated (control). Only one side of the arch was laser irradiated, representing the Diode Laser group, whereas the other side was not irradiated and then was considered the Control Group. The initial retraction of the canines started after 3 months of the premolar extractions, and it was further evaluated for 4 months. Metallic brackets, 0.022-0.028-inch slot (Ormco Corp., Orange, CA), were placed on canines, whereas the premolars and molars were properly banded. Bilaterally segmented arches made of stainless steel, 0.016, were adopted in conjunction with a closed Ni-Ti coil spring (9mm in length, G&H, Franklin, IN, USA), delivering a force of 50 g/side at maximum extension for the initial retraction of the canines (Figure 3 a and b). This force was measured with a dynamometer (commercial brand, Morelli).

Spring reactivation was made every 21 days with the same force value (150 g) and repeated until the closing of the extraction space. The amount of tooth movement was measured in millimeters was prompted by measuring the distance between the tip of the mesial cusp of the first molar and the tip of the canine cusp.

The speed of the tooth movement was obtained from the following formula $V = d/t$ in which V was the speed of the canine movement, d is the amount of canine movement in millimeters at the end of treatment, and t the time useful to accomplish the movement.

The measurement was done by using a digital caliper (Mitutoyo, Japan) before initiating the orthodontic treatment and recorded. At each reactivation interval, new impressions for each patient

of both upper and lower jaws were taken. Then a new measurement of the previous distance was recorded. On every reactivation date, the patient was asked about the pain experienced during the bygone period. These responses were ranked according to a visual pain scale and were also organized in a schedule.

The right side of the mandible was chosen to be irradiated with the laser beam, whereas the left side was considered the control without irradiation.

The treatment was performed with a 980-nm diode laser (Wiser Laser Doctor Smile, Lambda) operating at an 810-nm wavelength (1 W of output power, continuous wave of 66.7 J/cm²) that was equipped with a 0.6-mm optical fiber in continuous-wave mode. The areas were chosen to be irradiated the lingual and buccal periodontal ligament of the canines. Three areas Cervical, Middle and Apical, were irradiated. The cervical area was equipped with a diode laser for 10 s. The middle area was equipped with a diode laser for 20 s. The apical area was equipped with a diode laser for 10 s. The total energy density (dose) at each application was 8 J (2×40 s×100 mW). Protective eyewear was worn by the patients and the clinician to prevent injury from laser wavelength exposure. The laser regimen was performed after the closed NiTi coil spring was installed or activated (day 0), and on, 3-, 7-, and 14-day intervals after every activation.

At every 21-day interval, the distance measurement was compared between the diode laser and control group. After 6 months, the diode laser and control groups were examined by periapical radiographs to see if any damage developed in the adjacent periodontal ligament and dental tissues.

Every patient was asked about the pain experienced after spring activation describing a single value of no pain (0), mild pain (1), moderate pain (2), severe pain (3), intolerable pain (4).

4.1 Statistical Analysis

Numeric data are expressed as the mean and standard deviation (SD), and categoric variables are expressed as numbers and percentages. The data were compared by two-sample t-tests. To analyze the differences in pain levels between the diode laser and control groups during combined treatment stages, Man-Whitney U test was done. Statistical analyses were performed using SPSS software, version 11.0, for Windows. A P value < .05 was considered statistically significant.

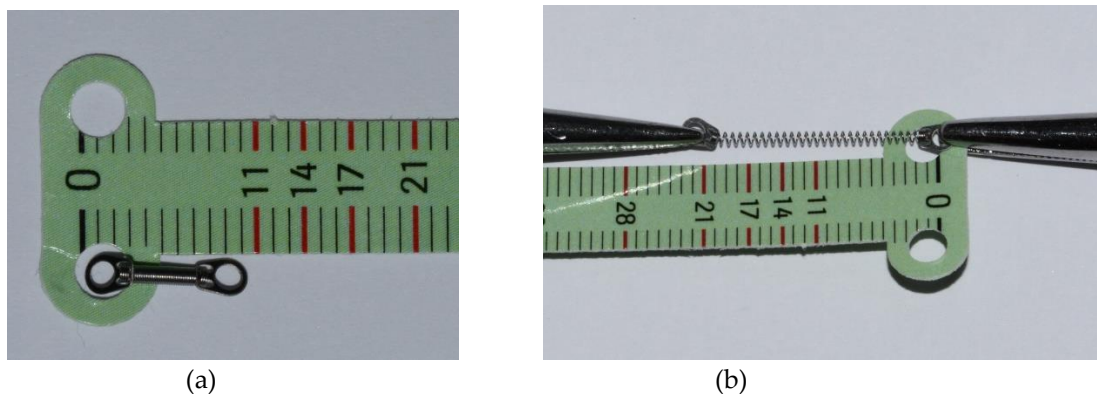


Figure 3: (a) The closed NiTi coil spring of 9 mm used for the study; (b) The NiTi coil spring activated with a force of 50g

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