European Journal of Musculoskeletal Diseases
ISSN 2038-4106/2023

Article

PHOTO-BIO-MODULATION AND PATIENT'S COMPLIANCE WITH CLEAR ALIGNERS

P. Caccianiga and G. Caccianiga

School of Medicine and Surgery, University of Milano-Bicocca, Monza, Italy

**Correspondence to*:
Gianluigi Caccianiga, DDS
School of Medicine and Surgery,
University of Milano-Bicocca,
20900 Monza, Italy
e-mail: gianluigi.caccianiga@unimib.it

ABSTRACT

Photobiomodulation (PBM) stimulates orthodontic tooth movements since it increases alveolar bone turnover. The aim of this study is to evaluate how PBM can influence orthodontic treatment with a clear aligner. A sample of 21 subjects was divided into a laser group (10 patients) and a control group (11 patients). All subjects were instructed to wear each clear aligner 12 hours a day for 2 weeks. PBM was given in the laser group every second week. The laser group successfully finished the treatment, while at the 3rd to the 5th aligner, the control group did not finish the treatment. Laser treatment is better than treatment without laser. PBM combined with aligners determines in 12 hours the same tooth movement obtained by wearing the aligner 22 hours a day. This aspect could be useful for those patients who prefer not to use the aligners during the day. PBM makes clear aligner treatment more comfortable since patients must wear the aligners for fewer hours than subjects treated orthodontically without laser.

KEYWORDS: *photobiomodulation, low-level laser therapy, tooth movement, clear aligners, biostimulation, diode laser*

INTRODUCTION

Studies on the effects of orthodontic treatment associated with lasers have recently increased. Most likely, the laser will be employed more to biostimulate orthodontic movement, potentially reducing the treatment time. A literature review shows surgery is the most effective technical method to accelerate the orthodontic movement, followed by Photobiomodulation (PBM) (1). Another review reported that PBM can not only reduce the time of the treatment but also reduce orthodontic pain (2).

PBM uses low-power lasers, such as diode lasers, to stimulate cells. PBM is simple to use, painless, and does not present side effects. In order to achieve results, it is necessary to use the correct laser parameters (2). The quantity of

Received: 19 april 2023
Accepted: 26 May 2023

ISSN: 2038-4106
Copyright © by BIOLIFE 2023
This publication and/or article is for individual use only and may not be further reproduced without written permission from the copyright holder. Unauthorized reproduction may result in financial and other penalties. **Disclosure: All authors report no conflicts of interest relevant to this article.**

tooth movement may vary depending on the type of laser and to parameters setting (such as wavelength, output and laser density) (3, 4). It is seen that the diode laser has a better penetration in human tissues and is an efficient device to be used in orthodontic clinical practice (5-6).

A correct energy density (Fluence= J/cm2) is of the utmost importance to obtain biological effects. The dosage of the laser's energy follows Arndt-Schulz's law: low dosages stimulate, and high dosages inhibit. However, if a too-low dosage is used, it cannot be compensated by increasing exposure time (7). Hence, the need was perceived to set the laser parameters correctly.

The laser effects applied in orthodontics are different and have been biologically demonstrated through studies on humans, animals and in vitro experiments. Various orthodontic biological laser effects have been demonstrated:

- stimulation of bone turnover (7-11)
- improvement in tooth movement (8, 10)
- reduction of post-orthodontic pain (2, 5)
- improvement in the production of keratinized gingiva (12)
- reduction of root resorption (6)
- stimulation of cell proliferation (13)
- stimulation of osteoblastic cells proliferation (11, 14)
- reduction of relapse (15)

Furthermore, no systemic side effects have been demonstrated for PBM.

PBM can stimulate bone turnover; therefore, it can also accelerate orthodontic movement without damaging either teeth or surrounding tissues (16).

Different studies clinically highlighted how PBM can accelerate orthodontic movement with fixed braces devices. On the other hand, none of the studies has highlighted PBM's effects on tooth movement in orthodontic treatments with invisible aligners. The null hypothesis of our study is that there is no difference between the laser treatment and the one without the laser. Since an increasing number of patients ask for aesthetic and less invasive treatments, we planned a study to verify if PBM, applied to the invisible aligners, can reduce the daily wearing of aligners. This study aims to check if PBM can accelerate tooth movement in orthodontic treatment with invisible clear aligners.

MATERIALS AND METHODS

Study design

The study was carried out in a private clinic in Bergamo, Italy. It was performed in accordance with the Declaration of Helsinki of 2013. The patients enrolled in the study received information, and they provided written consent. The standard protocol was to wear aligners for 22 (17, 18).

Inclusion and exclusion criteria

This pilot study allocated the patients into a laser group and a control group. Inclusion criteria were: vertebral maturation assessed on lateral cephalograms more advanced than CS4 (19), no previous orthodontic treatment, Class I malocclusion, permanent dentition completely erupted, incisal irregularity index from 4 mm to 6 mm (moderate crowding) in the mandibular arch.

The study sample comprised 21 patients (9 males and 12 females, ages 17 to 41) randomized into the study groups. The patient's clinical and demographic characteristics are reported in Table I.

Treatment protocol

All patients underwent a radiographic examination consisting of both orthopantomography and lateral cephalograms. Pre-treatment records consisted of initial dental casts and photos.

After 2 weeks, the same orthodontist who had carried out the baseline examinations examined patients in the laser and control groups. The dentist evaluated whether the aligner fitted properly and passively. If so, the subject was given the next aligner. If the aligner fitting was incorrect, the patient was instructed to wear the same aligner for 2 weeks, which continued until the aligner fitted correctly.

The laser group included 10 subjects (6 female, 4 male) who received external diode laser biostimulation (wavelength of 980 nm, continuous wave at 1 Watt output power) at each control visit. A flat-top optical fibre delivered the beam, and irradiation was administered by placing the beam outside the mouth, under the cheekbone at the level of the maxillary arch first, then at the level of the mandibular arch on the right and the left side. Finally, the flat top optical fibre was moved under the nose, firstly at the level of the maxillary arch, then at the level of the mandibular arch for 3 applications for each arch (Fig. 1).

The irradiation was performed for 50 seconds at each point (150 s for each arch). The energy density corresponding to an exposure time of 150 s per arch was 150J/cm2 (every second, the fluency was 1J/cm2). After the PBM, patients were instructed to wear each clear aligner 12 hours a day for 2 weeks.

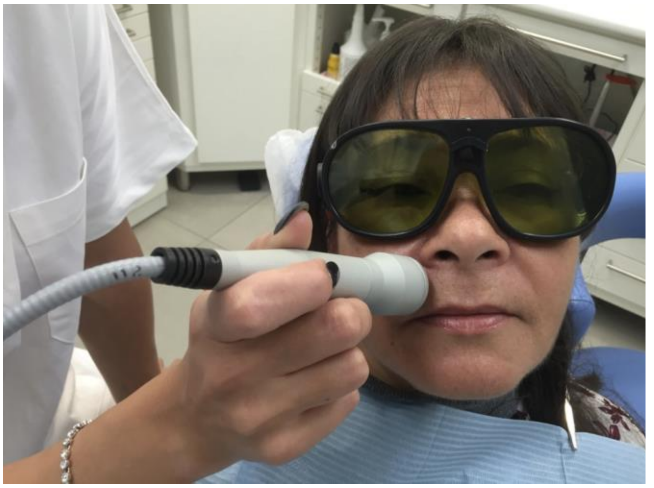

Fig. 1. *External laser bio stimulation with a flap top optical fiber. The beam was delivered by a flat-top optical fiber and irradiation was administered by placing the beam outside the mouth under the cheekbone at the level of the maxillary arch first, then at the level of the mandibular arch on the right and on the left side. Finally, the flat top optical fiber was moved under the nose, first at the level of the maxillary arch, then at the level of the mandibular arch for 3 applications for each arch.*

The control group included 11 patients (6 female, 5 male) who were instructed to follow the same protocol: to wear each aligner 12 hours a day for 2 weeks.

Clear Aligners were made of transparent pressure moulding sheets with thicknesses varying from 0.5 mm to 0.8 mm. Single resin attachments were used only for 25 canines that needed rotation (12 attachments in the control group, 13 in the laser group). The orthodontic factory made the Clin Check with "3Shape" software. Space analysis used Little's Irregularity index (20) in the lower arch from 3 to 3.

No patients received extraction orthodontic treatment or stripping. The expansion quantity was evaluated by measuring the inferior arch depth (distance between the most labial surface midpoint of the incisors to the mesial midpoint of the first molars) and the inferior arch perimeter (the sum of the individual segments: mesial of the left first molar to mesial of the left first premolar; width of left canine; distal of left lateral incisor to distal of right lateral incisor; width of right canine; mesial of right first premolar to mesial of the right first molar). Measures were carried out on digital models. The average of the increasing arch depth between the pre- and post-treatment was 1.76 mm, and the average of the increasing arch perimeter was 4.21 mm.

The mean of linear movement was 0.13±0.09 mm, while the mean rotational movement was 1.77±1.71°. The mean measurements of the two movements, linear and rotational, refer to all patients' anterior inferior arch from canine to canine.

Statistical analysis

Conventional descriptive statistics were carried out to analyze sample demographic and clinical characteristics. For comparisons between the two treatment groups, the t-test and the chi-squared test were used for numerical (age, crowding) and categorical (gender) characteristics.

In order to verify the null hypothesis, the P-value was calculated between the two treatment groups for the number of aligners correctly fitted at each follow-up visit.

RESULTS

Baseline findings

Descriptive statistics reported no differences between the two groups for age, gender and amount of crowding (Table I). Thus, the random assignment of participants to both treatment groups was validated.

The average age of the laser group was 26.6 years. The mean age of the control group was 25.5 years. The mean crowding (Irregularity Index) in the laser group was 4.80 mm, and in the control group was 4.98 mm (Table II).

There were more females than males, but no significant differences were seen in gender distribution between the control group and the laser one. Females were older than males with a greater standard deviation, but there was no significant difference between groups (P-value=0.3796) (Table II).

Outcomes

In the control group, the third, fourth or fifth aligners did not fit correctly (mean= 3.6 aligners) (Table III). In the control group, the protocol of 12 hours a day failed, and we had to turn to the standard protocol of 22 hours a day to finish the treatment. All laser group patients successfully completed the treatment. The mean treatment duration with the 12-hour protocol was 7.2±1.6 weeks in the control group (at that point, treatment was discontinued) and 40±2 weeks in the laser group.

DISCUSSION

The effect of PBM on tooth movement during orthodontic treatment with clear aligners is investigated in this study. In 12 hours, PBM produces the same tooth movement obtained by wearing the clear aligner 22 hours a day without PBM; this agrees with those studies that have demonstrated a reduction in treatment time using PBM (2).

Different lasers can be used, but the diode laser seems the most effective in orthodontic biostimulation (3, 6, 7). The

Table. I. *Baseline findings: gender, age distribution, crowding.*

Variables	Total	Control Group	Laser Group	Significance*
Patients (n)	21	11	10	
Age (mean±SD)	26±5.4	25.5±4.9	26.6±6	NS
Range age	17-41	17-31	20-41	
Female, n (%)	12 (57)	6 (55)	6 (60)	NS
Male, n (%)	9 (43)	5 (45)	4 (40)	NS
Crowding (Irregularity Index), mean±SD	4.89±0.53	4.98±0.55	4.80±0.51	NS

(n= Number, SD= Standard Deviation, NS= not significant).
**Significance for comparison of group means calculated by paired t-test.*

Table II. *Baseline findings: age distribution.*

Variables	Female	Male	P-Value
Mean Age	26.9	24.8	0.3796
SD	6.4	3.6	

(SD= Standard Deviation)

Table III. *Outcomes: number of aligners fitted correctly for each treatment and number of treatments finished successfully.*

Variables	Laser Group	Control Group	P-Value
Total number aligner (mean±SD)	22.1±1	3.6±0.8	0.001
Success/Unsuccess (n)	10/0	0/11	

(n= Number, SD= Standard Deviation)

parameter set is fundamental to having clinical results (5, 6). The external laser biostimulation with a flat-top optical fibre (wavelength of 980 nm and continuous wave at 1-watt output power) seems to have predictable results. The protocol of 150 seconds of irradiation for each arch is clinically effective.

The improvement in tooth movement could be due to the biostimulation of bone turnover (7, 13, 14). The exact mechanism of the PBM on the bone is not yet fully understood. In vitro studies show that the light at a lower radiation dosage is absorbed by the intracellular chromophores in the mitochondria, thus increasing cell proliferation through photochemical alterations (6, 9, 21). This mechanism includes the promotion of angiogenesis (22), production of collagen (23), osteogenic cell proliferation and differentiation (24), mitochondrial oxidation and adenosine triphosphate synthesis (25, 26). PBM can enhance the local blood flow, increasing the supply of circulating cells, nutrition, oxygen, and inorganic salts to bone lesions (27); this had already been noted by Kobu (10), who showed that intraosseous blood flow increased by approximately 80% in tissues treated with PBM, and oxygen tension by approximately 15%. Kawasaki and Shimizu (28) showed that PBM increased the number of osteoclasts on the pressure side during experimental tooth movement in rats. PBM can achieve these cellular effects because the beam has a tissue penetration from 2.2 cm to 5.9 cm (29).

CONCLUSIONS

PBM is useful in orthodontic clinical practice, especially when patients lack compliance and do not wear the aligners 22 hours a day. PBM can produce an expected dental movement with a reduced wearing time.

Author Contributions

G.C. designed the research study; G.C. performed the research; P.C. and G.C. wrote the manuscript; all authors contributed to editorial changes; all authors read and approved the final manuscript.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

1. Camacho AD. Dental movement acceleration: Literature review by an alternative scientific evidence method. *World Journal of Methodology*. 2014;4(3):151. doi:https://doi.org/10.5662/wjm.v4.i3.151
2. Sousa MVS, Pinzan A, Consolaro A, Henriques JFC, de Freitas MR. Systematic literature review: influence of low-level laser on orthodontic movement and pain control in humans. *Photomedicine and Laser Surgery*. 2014;32(11):592-599. doi:https://doi.org/10.1089/pho.2014.3789
3. Olmedo-Hernández OL, Mota-Rodríguez AN, Torres-Rosas R, Argueta-Figueroa L. Effect of the photobiomodulation for acceleration of the orthodontic tooth movement: a systematic review and meta-analysis. *Lasers in Medical Science*. 2022;37(5). doi:https://doi.org/10.1007/s10103-022-03538-8
4. Gomes MF, Goulart MDGV, Giannasi LC, et al. Effects of the photobiomodulation using different energy densities on the periodontal tissues under orthodontic force in rats with type 2 diabetes mellitus. *Braz Oral Res*. 2018;32:e61. doi:10.1590/1807-3107bor-2018.vol32.0061
5. Ren C, McGrath C, Yang Y. The effectiveness of low-level diode laser therapy on orthodontic pain management: a systematic review and meta-analysis. *Lasers in Medical Science*. 2015;30(7):1881-1893. doi:https://doi.org/10.1007/s10103-015-1743-4
6. Seifi M, Atri F, Yazdani MM. Effects of low-level laser therapy on orthodontic tooth movement and root resorption after artificial socket preservation. *Dental Research Journal*. 2014;11(1):61-66.

7. Sarmadi S, Tanbakuchi B, Hesam Arefi A, Chiniforush N. The Effect of Photobiomodulation on Distraction Osteogenesis. *J Lasers Med Sci*. 2019;10(4):330-337. doi:10.15171/jlms.2019.53
8. Sokouti Emamzadeh Hashemi I, Maleki D, Seyyed Monir SE, Ebrahimi A, Tabari R, Mousavi E. Effects of Diode Low-Level Laser Therapy of 810 Nm on Pulpal Anesthesia of Maxillary Premolars: A Double-Blind Randomized Clinical Trial [published online ahead of print, 2021 May 25]. *Eur Endod J*. 2021;6(2):155-159. doi:10.14744/eej.2020.41636
9. Farivar S, Malekshahabi T, Shiari R. Biological effects of low level laser therapy. *Journal of Lasers in Medical Sciences*. 2014;5(2):58-62.
10. Dharmaiah G, Prasad JLR, Balamurugan KS, Nurhidayat I, Fernandez-Gamiz U, Noeiaghdam S. Performance of magnetic dipole contribution on ferromagnetic non-Newtonian radiative MHD blood flow: An application of biotechnology and medical sciences. *Heliyon*. 2023;9(2):e13369. doi:10.1016/j.heliyon.2023.e13369
11. Nimeri G, Kau CH, Abou-Kheir NS, Corona R. Acceleration of tooth movement during orthodontic treatment - a frontier in Orthodontics. *Progress in Orthodontics*. 2013;14(1):42. doi:https://doi.org/10.1186/2196-1042-14-42
12. Gianluigi Caccianiga, Cordasco G, Leonida A, et al. Periodontal effects with self ligating appliances and laser biostimulation. *Dent Res J (Isfahan)*. 2012;9(S2). doi:https://doi.org/10.4103/1735-3327.109750
13. Ghaffar YKA, El Sharaby FA, Negm IM. Effect of low-level laser therapy on the time needed for leveling and alignment of mandibular anterior crowding. *Angle Orthod*. 2022;92(4):478-486. doi:10.2319/102721-795.1
14. Jivrajani SJ, Bhad Patil WA. Effect of Low Intensity Laser Therapy (LILT) on MMP-9 expression in gingival crevicular fluid and rate of orthodontic tooth movement in patients undergoing canine retraction: A randomized controlled trial [published correction appears in Int Orthod. 2020 Dec;18(4):895-896]. *Int Orthod*. 2020;18(2):330-339. doi:10.1016/j.ortho.2020.01.008
15. Salehi P, Heidari S, Nader Tanideh, Sepideh Torkan. Effect of low-level laser irradiation on the rate and short-term stability of rotational tooth movement in dogs. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2015;147(5):578-586. doi:https://doi.org/10.1016/j.ajodo.2014.12.024
16. Ang Khaw CM, Dalci O, Foley M, Petocz P, Darendeliler MA, Papadopoulou AK. Physical properties of root cementum: Part 27. Effect of low-level laser therapy on the repair of orthodontically induced inflammatory root resorption: A double-blind, split-mouth, randomized controlled clinical trial. *Am J Orthod Dentofacial Orthop*. 2018;154(3):326-336. doi:10.1016/j.ajodo.2018.04.022
17. Nucera R, Dolci C, Bellocchio AM, et al. Effects of Composite Attachments on Orthodontic Clear Aligners Therapy: A Systematic Review. *Materials (Basel)*. 2022;15(2):533. Published 2022 Jan 11. doi:10.3390/ma15020533
18. Al-Dboush RE, Al-Zawawi E, El-Bialy T. Do orthodontic treatments using fixed appliances and clear aligner achieve comparable quality of occlusal contacts?. *Evid Based Dent*. 2022;23(4):160-161. doi:10.1038/s41432-022-0844-8
19. Szemraj A, Wojtaszek-Słomińska A, Racka-Pilszak B. Is the cervical vertebral maturation (CVM) method effective enough to replace the hand-wrist maturation (HWM) method in determining skeletal maturation?-A systematic review. *Eur J Radiol*. 2018;102:125-128. doi:10.1016/j.ejrad.2018.03.012
20. İrezli EC, Şahin MF, Demir R, Baysal A. Intra-examiner and Inter-examiner Reproducibility in Irregularity Index Measurements. *Turk J Orthod*. 2019;32(3):160-164. doi:10.5152/TurkJOrthod.2019.18075
21. Amid R, Kadkhodazadeh M, Ahsaie MG, Hakakzadeh A. Effect of low level laser therapy on proliferation and differentiation of the cells contributing in bone regeneration. *Journal of Lasers in Medical Sciences*. 2014;5(4):163-170.
22. Dungel P, Hartinger J, Chaudary S, et al. Low level light therapy by LED of different wavelength induces angiogenesis and improves ischemic wound healing. *Lasers in Surgery and Medicine*. 2014;46(10):773-780. doi:https://doi.org/10.1002/lsm.22299
23. Massotti FP, Gomes FV, Mayer L, et al. Histomorphometric Assessment of the Influence of Low-Level Laser Therapy on Peri-Implant Tissue Healing in the Rabbit Mandible. *Photomedicine and Laser Surgery*. 2015;33(3):123-128. doi:https://doi.org/10.1089/pho.2014.3792
24. Mirza S, Sadiq MSK, Alqahtani A, et al. The effect of 805 nm near-infrared photobiomodulation on proliferation and differentiation of bone marrow stem cells in murine rats. *Eur Rev Med Pharmacol Sci*. 2021;25(20):6319-6325. doi:10.26355/eurrev_202110_27002

25. Ferraresi C, Kaippert B, Avci P, et al. Low-level Laser (Light) Therapy Increases Mitochondrial Membrane Potential and ATP Synthesis in C2C12 Myotubes with a Peak Response at 3-6 h. *Photochemistry and Photobiology*. 2014;91(2):411-416. doi:https://doi.org/10.1111/php.12397
26. Buravlev EV, Zhidkova TV, Vladimirov YA, Osipov AN. Effects of low-level laser therapy on mitochondrial respiration and nitrosyl complex content. *Lasers Med Sci*. 2014;29(6):1861-1866. doi:https://doi.org/10.1007/s10103-014-1593-5
27. Rico-Holgado S, Ortiz-Díez G, Martín-Espada MC, Fernández-Pérez C, Baquero-Artigao MR, Suárez-Redondo M. Effect of Low-Level Laser Therapy on Bacterial Counts of Contaminated Traumatic Wounds in Dogs. *J Lasers Med Sci*. 2021;12:e78. Published 2021 Dec 12. doi:10.34172/jlms.2021.78
28. Eid FY, El-Kenany WA, Mowafy MI, El-Kalza AR, Guindi MA. A randomized controlled trial evaluating the effect of two low-level laser irradiation protocols on the rate of canine retraction. *Sci Rep*. 2022;12(1):10074. Published 2022 Jun 16. doi:10.1038/s41598-022-14280-0
29. Hudson DE, Hudson DO, Wininger JM, Richardson BD. Penetration of Laser Light at 808 and 980 nm in Bovine Tissue Samples. *Photomedicine and Laser Surgery*. 2013;31(4):163-168. doi:https://doi.org/10.1089/pho.2012.3284