Photobiomodulation with Laser Technology in Fixed Orthodontic Treatment

Subjects: Dentistry, Oral Surgery & Medicine

Contributor: Paolo Caccianiga , Ileana Carminati , Gianluigi Caccianiga

Despite the growing demand for improving smile aesthetics and occlusal functionality, a significant percentage of patients still refuse or discontinue orthodontic treatment because of pain and discomfort related to this therapy. As consequence, controlling the pain experienced by patients during the same therapy represents a primary concern for both patients and clinicians. Pieces of evidence have suggested that photobiomodulation can reduce pain experienced by patients during the decrowding stage or during specific protocols, for example, rapid maxillary expansion. PBM can be performed with lasers and also with a light-emitting diode (LED) device.

photobiomodulation low-level laser therapy low-level laser (light) therapy

1. Introduction

The use of lasers has been proposed in orthodontics mainly for its excellent surgical characteristics and his decontaminating effects in the management of periodontitis and peri-implantitis [1][2][3][4][5][6]. In fact, small laser surgeries require less or no use of stitches, they have much more pleasant postoperative consequences and are well accepted by young patients. In recent years, studies on the photobiomodulating effects of laser in orthodontics have increased considerably; the laser is used to reduce pain during orthodontic movement [7][8][9][10], to reduce treatment times and to increase the quality and quantity of keratinized gingiva, which is often diminished during orthodontic treatments [9][11][12][13].

Photobiomodulation (PBM) is simple to use, painless, has no side effects and has virtually no contraindications. In fact, due to the characteristics described above, photobiomodulation also finds its use in other areas of dentistry, such as the treatment of periodontitis and oral surgery procedures, to promote healing, thanks to its biostimulating power, and reduce post-operative pain [5][6][7][8][9][10][11][12][13][14]. To obtain positive results, it is necessary to use the right laser parameters: the amount of energy absorbed by the moving tooth can vary depending on the type of laser and the parameters used (wavelength, beam coming out of the handpiece for biostimulation, for example). Lasers with wavelengths between 600 and 1100 m have better penetration into human tissue and are therefore more effective for use in clinical orthodontic practice [15].

Correct energy density (Fluence = J/cm^2) is of the utmost importance to achieve biological effects. The dosage of laser energy follows the Arndt–Schulz law: low doses stimulate, high doses inhibit. However, if too low a dose is used, one cannot compensate by increasing the exposure time. Here, the need to correctly configure the laser parameters was perceived [15].

The effects of lasers on orthodontic biology are different and have been demonstrated in humans, animals, and cell cultures, such as stimulation of bone remodeling, reduction in post-orthodontic pain, increase in height and the thickness of the keratinized gingiva in the erupted teeth in the alveolar mucosa, the reduction in root resorption and recurrences. Additionally, no systemic side effects have been demonstrated for PBM [16][17][18].

It appears that PBM is able to stimulate bone remodeling, so it may also accelerate orthodontic movement without damaging teeth and surrounding tissues [16][17][18].

The exact mechanism of PBM on bone has not yet been fully understood. In vitro studies show that low-energy light is absorbed by intracellular chromophores in mitochondria, thereby increasing cell proliferation through photochemical alterations. This mechanism includes promotion of angiogenesis, collagen production, proliferation and differentiation of osteogenic cells, mitochondrial respiration, and synthesis of adenosine triphosphate (ATP) [17][18][19].

Several studies have clinically shown how PBM can accelerate orthodontic movement with fixed orthodontic appliances. On the other hand, studies have highlighted the effects of PBM on tooth movement in orthodontic treatments with aligners [7][8].

External laser biostimulation with “Flat Top” fiber optics, designed by Professor Alberico Benedicenti [20] (980 nm wavelength and continuous wave with an output power of 1 to 3 watts) seems to have predictable results. This particular handpiece allows the operator to have the same focal spot, while also remaining a little distant from the target point. The protocol, which foresees 150 s of irradiation for each arch, with a continuous oscillatory movement of the operator on all the teeth of the two arches, seems clinically effective.

Unfortunately, the “operator” parameter is present in all the protocols proposed in the literature. It would be interesting to have a device capable of having a simple and reproducible application, “independent operator”.

2. Orthodontic Treatment

What new information does this session give? Studies using elastomeric separators or bands, maxillary orthodontic expansion, invisible removal aligners or agenesis cases were excluded. All studies of patients with each fixed orthodontic treatment have been included: conventional backets, straight-wire technique and self-ligating brackets.

What References Were Used to Support the Results? [8][21][22][23][24][25][26][27][28][29][30][31][32][33]

On the contrary, all studies of patients with each fixed orthodontic treatment have been included.

In one of these studies, patients treated by straight-wire technique with Equilibrium brackets (Dentaurum, Ispringen, Germany) or with In-Ovation C (GAC/Dentsply, Tokyo, Japan) self-ligating brackets [23] were compared. The results show that there is not a significant difference in average pain between bracket groups during the first week of active orthodontic treatment ($p > 0.05$).

The level of dental crowding of treated patients was also not the same. Some patients had slight crowding [24] or level up to 5 mm [23]. Other subjects had 3–5 mm maxillary dental crowding [21][25].

In the study of Lo Giudice et al. [8] 90 subjects were divided into three groups with different crowding: mild (3–5 mm), moderate (5–7 mm), and severe (>7 mm). The authors did not find differences in the pain perceived among examined patients with mild, moderate and severe mandibular anterior crowding. However, there is no specific indication for the usage of PBM according to the amount of crowding.

In some treatments, the subjects were subjected to bilateral extraction of the first upper premolars and retraction of the canines to correct protrusion and dental crowding. This means that greater forces have been used to achieve greater displacement of some teeth, using springs and to obtain a good posterior anchorage transpalatal bars, banding and Nance button were used [22][25][26][27][28][29][30][31][32][33].

3. Laser Procedures

What new information does this session give? The lasers used had a different type, wavelength and power. In most cases, patients whose mouths were divided into a part treated with PBM and a placebo part, and a difference in perceived pain between the irradiated arch and the non-irradiated arch was noticed.

What References Were Used to Support the Results? [23][25][27][28][34]

In most studies, the procedure was carried out in an isolated room, using protective glasses for the operator, patient and dental assistant [27]. To confuse the patient and allow the placebo effect, the non-irradiated side was treated in the same way but with the machine turned off. To prevent the perception of the beeping emitted by the laser, music was played at a high volume [27][28].

Therefore, patients could not distinguish between the placebo and experimental sides [25].

An article indicates a beneficial effect even on the side not treated with lasers, indicating that there is a generalized effect within the trigeminal system. However, there have been no effects on extra-trigeminal sensitivity. The authors hypothesize that PBM may have reduced peripheral sensitization of Aδ fibers and C-related nerve fibers [23].

One of the effects of laser therapy with split mouth is the probability of carry-across effects of the laser beam from one side to the other. Many authors used a plastic shield like a barrier at the midline to limit the laser beam's penetration and, perchance, alter the results [27][28].

The lasers used had different type, wavelength and power. The irradiated dosimetry, energy density, timing, points on each side and number of monthly applications were also not the same. For example, in one of these studies, patients were first subjected to the alignment and leveling stages with nickel titanium archwires, and then, when the canine retraction began, with 0.018 in stainless steel wires, laser therapy was used [25].

A 3-week low-laser therapy model can be convenient in clinical practice as it coincides with conventional orthodontic appointments [27].

4. Dosages and Ways of Energy Distribution

What new information does this session give? Low-level laser therapy usually uses the following parameters: a power density between 5 and 150 mW × cm^{-2}, red and NIR wavelength range of 600–1000 nanometers, applied for 30 to 60 s per point.

What References Were Used to Support the Results? [33][35]

Low-level laser therapy usually uses the following parameters: a power density between 5 and 150 mW × cm^{-2}, red and NIR wavelength range of 600–1000 nanometers, applied for 30 to 60 s per point. The resulting therapeutic effect depends on energy density measured in joules (J) per cm^2. The effects of PBM depend upon the different tissues, cell type, irradiation parameters, time of exposure and redox state of the cell [33].

There is a biphasic dose response which underlines the existence of optimal irradiation and dose parameters. To make laser therapy effective, the parameters need to be within the biostimulatory dose windows.

A higher dosage than optimal has a negative therapeutic outcomes. On the contrary, a lower dosage than optimal has a diminished effect.

For the success of the treatment are necessary specific wavelength and energy (in J), energy density (J/cm^2), power density and duration parameters [35].

5. Statistically Significant Results

What new information does this session give? Most of their results show a statistically significant difference in perceived pain between the irradiated arch and the non-irradiated arch. Three authors did not find statistically significant results in favor of PBM, but they used different laser parameters.

What References Were Used to Support the Results? [9][21][22][23][24][25][27][28][29][30][34][35]

In most cases, studies have a split-mouth scheme therapy. The results show a statistically significant difference in perceived pain between the irradiated arch and the non-irradiated arch [23][28][29][34].

In the Sobouti et al. study, PBM contributed to about 12.1% reduction in painful sensation in the laser side compared with the matched placebo side [25].

Others studies shows that the irradiated side had a significant reduction in the average range of dental pain at 3, 7, and 14 days after laser treatment [30][34].

In the study of Dominguez et al., the results show that the highest pain intensity takes place within the first 48 h in the side with treatment and without, then a slight pain reduction in the laser group was observed [22].

In the study by Alam et al., all patients are randomly divided into 4 groups: PBM + self-ligating bracket, PBM + conventional bracket, non-PBM + self-ligating bracket, and non-PBM + conventional bracket function. The authors revealed PBM + self-ligating results as the best and PBM + conventional therapy as the 2nd best in lessened pain perception [35].

In another study, a statistically significant difference between the placebo/control groups and the irradiated group was found. In the first case, the peak of pain appeared on the 2nd day, ending around day 6–7. In the second case, the peak of pain came after 6 h and disappeared on day 4, and patients then found a reduced duration of pain [9].

In three studies, the results do not show a statistically significant difference for relieving orthodontic pain sensation following the use of laser therapy [21][24][30].

In the study by Al Sayed et al. [24], however, the mean pain scores found in the laser group were less than those of the placebo group in all studied time points. This indicates some clinical efficiency of PBM despite the absence of statistical significance.

6. Different Parameters: Age and Gener, Method of Measuring Pain and Devices

What new information does this session give? No significant difference was found in the pain sensation between males and females, nor between adolescents and adults. Some studies have used the Visual Analogic Scale (VAS), a subjective method. Other articles used a questionnaire based on a numeric rating scale (NRS) of evaluation. In many studies, the protocol involves the use of the device in different points of the mouth and for a variable period of time.

What References Were Used to Support the Results? [8][21][23][25][26][27][28][30][34][36]

It is known that pain perception can be affected by different individual parameters, such as age, gender, pain threshold, magnitude of the applied force, emotional status, cultural differences, and previous pain experiences.

In several studies, however, no significant difference was found in the pain sensation between males and females, nor between adolescents and adults [27][28].

It is also important to remember that the most sensitive age might be between 13 and 16 years old.

Since, in these split-mouth designs, each patient was matched with himself/herself, individual variations have a lower impact on results [25].

The recording of the painful sensation was performed with different parameters. Some studies have used the Visual Analogic Scale (VAS). It is a widely accepted method for measuring and showing differences in pain reported by patients; it is reliable, understandable by patients, sensitive, and reproducible. Although it is a subjective method, it is reliability in scoring pain at different time points when a big difference among participants is expected.

Other articles used a questionnaire based on a numeric rating scale (NRS) of evaluation to investigate the effects of laser therapy on pain sensation. It is highly correlated with VAS. This choice was also made to allow younger patients to comprehend the method of data collection [36].

Often, the method of administration of laser therapy is unclear but, above all, not reproducible. In many studies, the protocol involves the use of the device in different points of the mouth and for a variable period of time. To increase the reliability of the method, many authors had orthodontic treatment and laser applications performed by the same operator [8][21][23][26][30][34]. Unfortunately, even the individual operator is not able to reproduce his work in the same way over time. It is difficult to use in the repeatable way at each session.

7. New Perspectives wirh LED Devices in Orthodontics

What new information does this session give? ATP38 consists of a multi-plate system emitting polychrome cold light with a wavelength combination of 450 to 835 m. The results obtained with it are very interesting and seem equivalent to those with the use of diode lasers, in terms of pain, although for now they have been applied to different orthodontic techniques. The difference is that LEDs are able to evenly apply energy to all areas affected by orthodontic equipment and can be considered an “independent operator”.

What References Were Used to Support the Results? [10][11]

In a recent study by Lo Giudice et al. in 2020 [11], and in a study by Caccianiga et al. in 2022 [10], ATP38 was used, respectively, to speed up fixed orthodontic treatment and to relieve pain from rapid palatal expansion. This device is equipped with a multi-panel system with a combination of wavelengths from 450 to 835 nm depending on therapeutic indication.

ATP38 consists of a multi-plate system emitting polychrome cold light with a wavelength combination of 450 to 835 m. The biostimulation scheme used, according to the manufacturer’s instructions, consists of 6 min of irradiation producing a total of 48 J/cm^2 of fluence, calculated as the sum of the fluences produced by the light source (16 J/cm^2) of each of the three active panels (16 J/cm^2 × 3 = 48 J/cm^2). These parameters are based on a fixed distance of 4 cm from the cheek side panels and the lip side panel. Since 48 J/cm^2 is less than the amount of fluence used for the orthodontic photobiostimulation, three consecutive irradiation cycles were used, for a total duration of 18 min and 144 J/cm^2 of fluence (48 J/cm^2 × 3 cycles), with 1 min of rest between each cycle.

References

1. Caccianiga, G.; Rey, G.; Baldoni, M.; Caccianiga, P.; Baldoni, A.; Ceraulo, S. Periodontal Decontamination Induced by Light and Not by Heat: Comparison between Oxygen High Level Laser Therapy (OHLLT) and LANAP. Appl. Sci. 2021, 11, 4629.
2. Caccianiga, G.; Rey, G.; Caccianiga, P.; Leonida, A.; Baldoni, M.; Baldoni, A.; Ceraulo, S. Rough Dental Implant Surfaces and Peri-Implantitis: Role of Phase- Contrast Microscopy, Laser Protocols, and Modified Home Oral Hygiene in Maintenance. A 10-Year Retrospective Study. Appl. Sci. 2021, 11, 4985.
3. Caccianiga, G.; Rey, G.; Caccianiga, P.; Leonida, A.; Baldoni, M.; Baldoni, A.; Ceraulo, S. Peri-Implantitis Management: Surgical versus Non-Surgical Approach Using Photodynamic Therapy Combined with Hydrogen Peroxide (OHLLT—Oxygen High Level Laser Therapy). A Retrospective Controlled Study. Appl. Sci. 2021, 11, 5073.
4. Caccianiga, G.; Rey, G.; Caccianiga, P.; Leonida, A.; Baldoni, M.; Baldoni, A.; Ceraulo, S. Laser Management of Peri-Implantitis: A Comparison between Photodynamic Therapy Combined with Hydrogen Peroxide (OHLLT) and OHLLT + Er:YAG Laser). A Retrospective Controlled Study. Appl. Sci. 2021, 11, 6771.
5. Caccianiga, G.; Rey, G.; Baldoni, M.; Caccianiga, P.; Porcaro, G.; Baldoni, A.; Ceraulo, S. Laser Decontamination and LED Photobiomodulation Promote Bone Regeneration and Wound Healing by Secondary Intention, in Alveolar Ridge Preservation-Clinical and Radiographic Evaluation: A Pilot Experience. Photobiomodul. Photomed. Laser Surg. 2022, 40, 343–354.
6. Caccianiga, G.; Ferri, L.; Baldoni, M.; Bader, A.A.; Caccianiga, P. Magnetic Mallet and Laser for a Minimally Invasive Implantology: A Full Arch Case Report. Appl. Sci. 2022, 12, 9995.
7. Nicotra, C.; Polizzi, A.; Zappala, G.; Leonida, A.; Indelicato, F.; Caccianiga, G. A comparative assessment of pain caused by the placement of banded orthodontic appliances with and without low-level laser therapy: A randomized controlled prospective study. Dent. J. 2020, 8, 24.
8. Lo Giudice ANucera, R.; Perillo, L.; Paiusco, A.; Caccianiga, G. Is Low-Level Laser Therapy an Effective Method to Alleviate Pain Induced by Active Orthodontic Alignment Archwire? A Randomized Clinical Trial. J. Evid. -Based Dent. Pract. 2019, 19, 71–78.
9. Caccianiga, G.; Lo Giudice, A.; Longoni, S.; Ceraulo, S.; Baldoni, M.; Leonida, A. Low-level laser therapy protocols in dental movement acceleration and in pain management during orthodontic treatment. J. Biol. Regul. Homeost. Agents 2019, 33, 59–68.
10. Caccianiga, G.; Caccianiga, P.; Baldoni, M.; Lo Giudice, A.; Perillo, L.; Moretti, N.; Ceraulo, S. Pain Reduction during Rapid Palatal Expansion Due to LED Photobiomodulation Irradiation: A Randomized Clinical Trial. Life 2022, 12, 37.

11. Lo Giudice, A.; Nucera, R.; Leonardi, R.; Paiusco, A.; Baldoni, M.; Caccianiga, G. A Comparative Assessment of the Efficiency or Orthodontic Treatment with and Without Photobiomodulation During Mandibular Decrowding in Young Subjects: A Single-Center, Single-Blind Randomized Controlled Trial. Photobiomodulation Photomed. Laser Surg. 2020, 38, 272–279.
12. Caccianiga, G.; Lo Giudice, A.; Paiusco, A.; Portelli, M.; Militi, A.; Baldoni, M.; Nucera, R. Maxillary Orthodontic Expansion Assisted by Unilateral Alveolar Corticotomy and Low-Level Laser Therapy: A Novel Approach for Correction of a Posterior Unilateral Cross-Bite in Adults. J. Lasers Med. Sci. 2019, 10, 225–229.
13. Caccianiga, G.; Paiusco, A.; Perillo, L.; Nucera, R.; Pinsino, A.; Maddalone MCordasco, G.; Lo Giudice, A. Does Low-Level Laser Therapy Enhance the Efficiency of Orthodontic Dental Alignment? Results from a Randomized Pilot Study. Photomed. Laser Surg. 2017, 35, 421–426.
14. Scribante, A.; Gallo, S.; Pascadopoli, M.; Soleo, R.; Di Fonso, F.; Politi, L.; Venugopal, A.; Marya, A.; Butera, A. Management of Periodontal Disease with Adjunctive Therapy with Ozone and Photobiomodulation (PBM): A Randomized Clinical Trial. Photonics 2022, 9, 138.
15. Maggioni, M.; Attanasio, T.; Scarpelli, F. I Laser in Odontoiatria; Piccin: Padova, Italy, 2009.
16. Caccianiga, G.; Crestale, C.; Cozzani, M.; Piras, A.; Mutinelli, S.; Lo Giudice, A. Cordasco, Low level laser therapy and invisible removal aligners. J. Biol. Regul. Homeost. Agents 2016, 30, 107–111.
17. Leonida, A.; Paiusco, A.; Rossi, G.; Carini, F.; Baldoni, M.; Caccianiga, G. Effects of low-level laser irradiation on proliferation and osteoblastic differentiation of human mesenchymal stem cells seeded on a three-dimensional biomatrix: In vitro pilot study. Lasers Med. Sci. 2013, 28, 125–132.
18. Caccianiga, G.; Cambini, A.; Donzelli, E.; Baldoni, M.; Rey, G.; Paiusco, A. Effects of laser biostimulation on the epithelial tissue for keratinized layer differentiation: An in vitro study. J. Biol. Regul. Homeost. Agents 2016, 30, 99–105.
19. Caccianiga, G.; Baldoni, M.; Ghisalberti, C.A.; Paiusco, A. A Preliminary In Vitro Study on the Efficacy of High-Power Photodynamic Therapy (HLLT): Comparison between Pulsed Diode Lasers and Superpulsed Diode Lasers and Impact of Hydrogen Peroxide with Controlled Stabilization. Biomed Res. Int. 2016, 2016, 1386158.
20. Amaroli, A.; Ravera, S.; Parker, S.; Panfoli, I.; Benedicenti, A.; Benedicenti, S. An 808-nm Diode Laser with a Flat-Top Handpiece Positively Photobiomodulates Mitochondria Activities. Photomed. Laser Surg. 2016, 34, 564–571.
21. Celebi, F.; Turk, T.; Bicakcia, A.A. Effects of low-level laser therapy and mechanical vibration on orthodontic pain caused by initial archwire. Am. J. Orthod. Dentofac. Orthop. 2019, 156, 87–93.
22. Domínguez, A.; Gómez, C.; Palma, J.C. Effects of low-level laser therapy on orthodontics: Rate of tooth movement, pain, and release of RANKL and OPG in GCF. Lasers Med. Sci. 2013, 30, 915–

923.

23. Wu, S.; Chen, Y.; Zhang, J.; Chen, W.; Shao, S.; Shen, H.; Zhu, L.; Ye, P.; Svensson, P.; Wang, K. Effect of low-level laser therapy on tooth-related pain and somatosensory function evoked by orthodontic treatment. Int. J. Oral Sci. 2018, 10, 22.
24. Al Sayed Hasan Sultan, K.; Ajaj, M.; Voborná, I.; Hamadah, O. Low-level laser therapy effectiveness in reducing initial orthodontic archwire placement pain in premolars extraction cases: A single-blind, placebo-controlled, randomized clinical trial. BMC Oral Health. 2020, 20, 209.
25. Sobouti, F.; Khatami, M.; Chiniforush, N.; Rakhshan, V.; Shariati, M. Effect of single-dose low-level helium-neon laser irradiation on orthodontic pain: A split-mouth single-blind placebo-controlled randomized clinical trial. Prog. Orthod. 2015, 16, 32.
26. Isola, G.; Matarese, M.; Briguglio, F.; Grassia, V.; Picciolo, G.; Fiorillo, L.; Matarese, G. Effectiveness of Low-Level Laser Therapy during Tooth Movement: A Randomized Clinical Trial. Materials. 2019, 12, 2187.
27. Qamruddin, I.; Khursheed Alam, M.; Mahroof, V.; Fida, M.; Khamis, M.F.; Huseine, A. Effects of low-level laser irradiation on the rate of orthodontic tooth movement and associated pain with self-ligating brackets. Am. J. Orthod. Dentofac. Orthod. 2017, 152, 622–630.
28. Qamruddin, I.; Alam, M.K.; Abdullah, H.; Kamran, M.A.; Jawaid, N.; Mahroof, V. Effects of single-dose, low-level laser therapy on pain associated with the initial stage of fixed orthodontic treatment: A randomized clinical trial. Korean J. Orthod. 2018, 48, 90.
29. Doshi-Mehta, G.; Bhad-Patil, W.A. Efficacy of low-intensity laser therapy in reducing treatment time and orthodontic pain: A clinical investigation. Am. J. Orthod. Dentofac. Orthop. 2012, 141, 289–297.
30. Storniolo-Souza, J.; Mangialardo Lima, L.; Pinzan, A.; Alvarez, F.; Costa Pereira, S.C.; Janson, G. Influence of low-level laser irradiation on orthodontic movement and pain level—A randomized clinical trial. Orthod. Waves. 2020, 79, 105–112.
31. Guram, G.; Reddy, R.K.; Dharamsi, A.M.; Syed Ismail, P.M.; Mishra, S.; Prakashkumar, M.D. Evaluation of Low-Level Laser Therapy on Orthodontic Tooth Movement: A Randomized Control Study. Contemp Clin. Dent. 2018, 9, 105–109.
32. Pandis, N.; Walsh, T.; Polychronopoulou, A.; Katsaros, C.; Eliades, T. Split-mouth designs in orthodontics: An overview with applications to orthodontic clinical trials. Eur. J. Orthod. 2013, 35, 783–789.
33. Bjordal, J.M. Low level laser therapy (LLLT) and World Association for Laser Therapy (WALT) dosage recommendations. Photomed. Laser Surg. 2012, 30, 61–62.

34. Domìnguez, A.; Velàsquez, S.A. Effect of Low-Level Laser Therapy on Pain Following Activation of Orthodontic Final Archwires: A Randomized Controlled Clinical Trial. Photomed. Laser Surg. 2013, 31, 36–40.
35. Alam, M.K. Laser-Assisted Orthodontic ToothMovement in Saudi Population: A Prospective Clinical Intervention of Low-Level Laser Therapy in the 1st Week of Pain Perception in Four Treatment Modalities. Pain Res. Manage. 2019, 2019, 6271835.
36. Jensen, M.P.; Karoly, P.; Braver, S. The measurement of clinical pain intensity: A comparison of six methods. Pain 1986, 27, 117–126.

Retrieved from https://encyclopedia.pub/entry/history/show/97933