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Review

Photobiomodulation with Laser Technology to Reduce Pain Perception during Fixed Orthodontic Treatment: Literature Review and New Perspectives with LED Devices

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Abstract: 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. Recent 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. Nonetheless, few studies on the latter are still present in the literature. The aim of this research is to evaluate the efficacy of photobiomodulation (PBM) with Laser devices in pain management in fixed orthodontic treatment. Only 14 of all articles met the inclusion and exclusion criteria and were therefore used to conduct the research. The different studies compared, in most cases, patients whose mouths were divided into a part treated with PBM and a placebo part. Most of their results show a statistically significant difference in perceived pain between the irradiated arch and the nonirradiated arch. Three authors did not find statistically significant results in favor of PBM, but they used different laser parameters. To obtain generally valid studies, with consistent and reproducible results, it is necessary to standardize the different laser parameters used. LED is less operator-dependent than laser and PBM using this technology seems to have a biological basis similar to that with lasers. In some studies, its clinical efficacy in pain reduction in some orthodontic therapies has been verified. Finally, this article aims to consider LED technology as a future prospect of research on PBM use in orthodontics.

Keywords: photobiomodulation; low-level laser therapy; low-level laser (light) therapy; LED; laser; pain; tooth movement; fixed orthodontic treatment

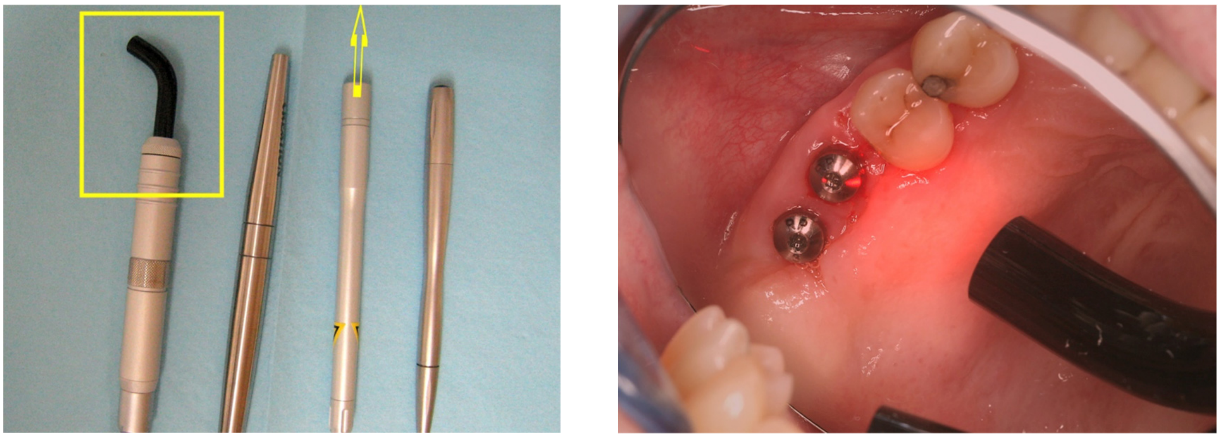
Citation: Caccianiga, P.; Carminati, I.; Caccianiga, G. Photobiomodulation with Laser Technology to Reduce Pain Perception during Fixed Orthodontic Treatment: Literature Review and New Perspectives with LED Devices. *Inventions* **2023**, *8*, 46. https://doi.org/10.3390/inventions8010046

Academic Editors: Chien-Hung Liu and Chun-Liang Lin

Received: 28 November 2022
Revised: 13 December 2022
Accepted: 3 January 2023
Published: 9 February 2023

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 [1–6] (Figure 1). 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 [7–10], to reduce treatment times and to increase the quality and quantity of keratinized gingiva, which is often diminished during orthodontic treatments [9,11–13].



(**a**) (**b**)

Figure 1. (**a**) Specific laser handpiece for photobiomodulation (in yellow, other ones are for biostimulation and decontamination settings); (**b**) PBM with laser in implantology.

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 [5–14]. 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 [16–18].

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

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) [17–19].

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 (Figure 2), 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.

Figure 2. Flat Top handpiece for PBM in orthodontic treatment.

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".

This problem seems to be solved by using LED devices such as the ATP38 (Biotech Dental, Salone-de-Provence, France) [Figure 3], a biostimulation device characterized by LED panels that emit a combination of 8 different wavelengths, from 400 to 820 nm. It is made by Polychrome collimated semiconductors (PCSC) that emit cold polychromatic lights, promoting cell metabolism and producing a stimulating effect on the production of ATP (adenosine triphosphate, the main energy molecule of the cell, which constitutes the structural unit of DNA). The biological effects have not been demonstrated with studies in the literature; however, its clinical efficacy in reducing pain in orthodontics thanks to photobiomodulation has been demonstrated by some studies [10,11]. The ATP38, capable of uniformly applying energy to all areas affected by orthodontic equipment, the maxillary and mandibular arches, and the temporomandibular joints can indeed be considered an "independent operator".

(**a**) (**b**)

Figure 3. (**a**,**b**) LED photobiomodulation with ATP38.

The main difference with photobiomodulation with laser techniques is that lasers use a coherent light beam, while LEDs use an incoherent light beam (Figures 4 and 5).

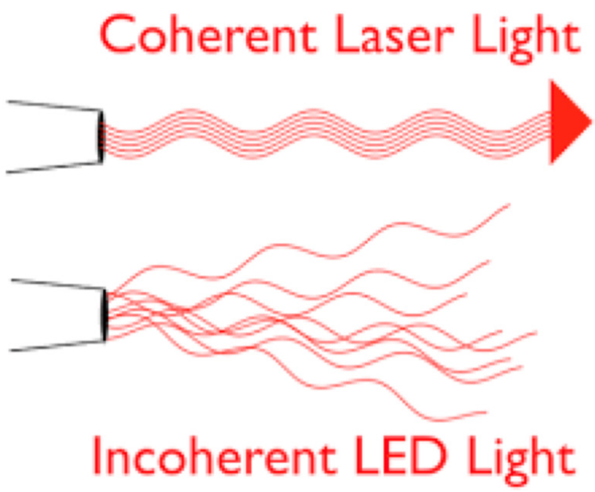


Figure 4. Difference between laser and LED light beams.

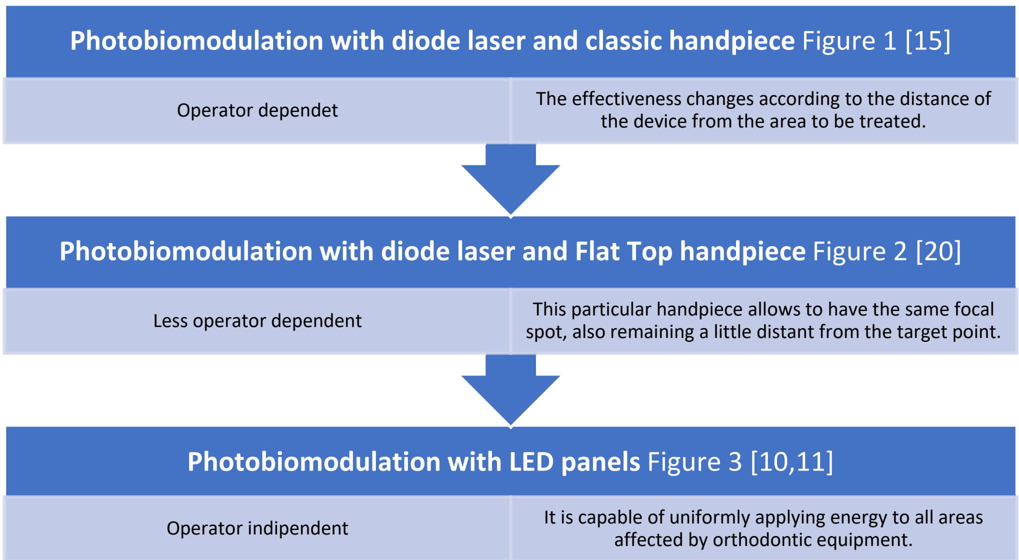


Figure 5. Flow-chart of different PBM devices, in chronological order.

The aim of this research is to identify in the literature the use of PBM in subjects undergoing fixed orthodontic treatment, to reduce the painful perception and discomfort that it causes.

2. Methods

The research was conducted at the beginning of 2022 by using Web of Science, PubMed and Scopus databases. Hand-searching was not performed.

Keywords used were "photobiomodulation", "laser", "led", "orthodontic", "dental movement", "tooth movement", and "pain".

Inclusion and exclusion criteria were determined prior to reading the retrieved abstracts.

Inclusion criteria were as follows:

- Articles published in the last 10 years;
- Studies published in English language;
- Studies conducted on human species;
- Participants that underwent fixed orthodontic treatment without limitation in gender, age, race and social economic status;
- Randomized clinical trials which analysed the effectiveness of PBM in reducing orthodontic pain compared with placebo group (simulated pain treatment) and/or a control group (no treatment of any kind);
- Studies that used the visual analogic scale (VAS), the numerical scale of evaluation or another type of questionnaire to evaluate the duration and intensity of pain.

Exclusion criteria were as follows:

- Articles not written in English language;
- Studies were cases or letter reports, review articles, cohort studies, opinion articles, abstract and descriptive;
- In vitro or animal studies;
- Participants with pain caused by acute or chronic dental, periodontal or gum disorders;
- Studies of patients compromised by neurological and psychiatric disorders, systemic diseases or chronic pain;
- Participants not subjected to fixed orthodontic treatment such as studies on orthodontic elastomeric devices or similar.

The articles found in the search were selected based on the relevance of their abstract, title and keywords. Publications addressing questions which seemed relevant to the specifications of the problem, were read in full and either included for further analysis or excluded.

3. Results

A total of 321 results have been identified through database searching: 164 on Web of Science, 71 on PubMed and 86 on Scopus. The filters "last 10 years" and "human species" have been applied, finding the following articles: 136 on Web of Science, 52 on PubMed and 63 on Scopus. After excluding duplicates and reviewing titles and abstracts, 52 articles were evaluated in full text.

Only 14 of all articles met the inclusion and exclusion criteria and were therefore used to conduct the research. All the articles analyzed concern the use of laser technology to relieve pain during fixed orthodontic therapy. Although there are studies on the effects of LED panels such as ATP38 on the acceleration of orthodontic movement [11] and on the reduction in pain in orthodontics [10], there is a lack of studies regarding their specific use in the treatment of fixed orthodontics. Therefore, in the comparison table presented in the results, there are only laser photobiomodulation studies; however, a part of the discussion was also dedicated to protocols with LED panels, as new perspectives.

The selected studies that evaluated the effectiveness of PBM for orthodontic pain used different parameters, such as wavelength, power output, energy dose, exposure duration, focal spot area, power density, energy density, and frequency of treatment.

Moreover, the subjects examined differ in age, gender, cultural and social difference, malocclusion, etc.

Table 1 shows the different parameters of each study.

Table 1. The different parameters of each study.

Articles	Study Design	Subject	Orthodontic Treatment	Device	Wavelength and Power	Dose	Total Energy	Pain Measurement	Statistically Significant Pain Reduction
Celebi et al. (2019) [21]	RCT (split-mouth)	60: 30 F—30 M Age: 11–23	Fixed orthodontic treatment, slot 0018 × 0.025 inch	GaAlAs diode laser	820 nm 110.3 mW	1.76 J/cm^2, 3 points/side for 16 s each. Only one dose	Not indicated	VAS 2 h, 6 h, 24 h, 2 d, 3 d and 7 d	No
Dominguez et al. (2013) [22]	Single-blind RCT (split mouth)	59: 40 F—19 M AGE: 20–30	Mini brackets Equilibrium and self-ligating brackets slot 0.022 inch	GaAlAs laser	830 nm 100 mW	80 J/cm^2, 2.2 J vestibular and palatal surface, for 22 s each Only one dose: T0	4.4 per tooth	VAS after 2 h (T1), 6 h (T2), 24 h (T3), 2 days (T4), 3 days (T5), and 7 days(T6)	Yes
Wu et al. (2018) [23]	Double-blinded RCT	40: 30 F—10 M Age: 12–33	Self-ligating brackets slot 0.022 inch	GaAlAs diode laser	810 nm 400 mW	2 J/cm^2 3 points/side, for 20 s each Multiple doses: 0 h, 2 h, 24 h, 4 d, and 7 d	Not indicated	Quantitative sensory testing (QST) at 0 h, 2 h, 24 h, 4 d, and 7 d	Yes
Al Sayed et al. (2020) [24]	Single-blind, placebo-controlled, RCT	26 Age 16–24	Fixed orthodontic treatment (Extraction)	GaAlAs laser	830 nm 150 mW	4.25 J/cm^2 2 point/side for 15 s for each tooth Only one dose	2 J per point	VAS At 1, 6, 24, 48, and 72 h	No
Lo Giudice et al. (2019) [8]	RCT	84: 43 F—41 M Age: 16.5 ± 2.8	Self-ligating appliance slot 0.022 inch	diode laser	980 nm 1 W	24–27 J/cm^2 A total of 50 s Multiple doses: 3 times at intervals of 2 min	150 J/cm^2 for mandibular arch	NRS at 2 h, 6 h, 24 h, from day 2 to 7	Yes
Sobouti et al. (2015) [25]	Single-blind RCT (split-mouth) placebo-controlled	27: 11 F—16 M Age: 12–21	Metal pre-adjusted brackets (Extractions)	He-Ne laser	632.8 nm 10 mW	6 J/cm^2 buccal and palatal: radical apical for 80 s and coronal for 40 s Only one dose: T0	Not indicated	VAS on the 1, 2, 4, and 7 days	Yes
Isola et al. (2019) [26]	RCT (split mouth)	41: 20 F—21 M Age: 10–18	Metal brackets slot 0.022–0.028 inch (Extractions)	Diode laser	810 nm 1 W	66.7 J/cm^2, 3 points/side for 15 s each Multiple doses: 0 d, 3 d, 7 d, 14 d and every 15 d	8 J (2 × 40 s × 100 mW)	VAS at 3, 7, and 14 days	Yes
Qamruddin et al. (2017) [27]	Single-blinded RCT (split-mouth)	20: 10 F—10 M Age: 12–25	Self-ligating MBT brackets slot 0.022-inch (Extractions)	GaAlAs diode laser	940 nm 100 mW	7.5 J/cm^2, 5 points/side, 3 s for each point Multiple doses: T0, T1 and T2	Not indicated	NRS 4 h and 24 h after each application	Yes
Dominguez et al. (2013) [28]	RCT	10: 5 F—5 M Age: 12–16	Fixed orthodontic treatment slot 0.018 inch (Extractions)	Diode laser	670 nm 200 mW	6.37 W/cm^2, 3 surface, 3 min on each surface Multiple doses: 0, 1, 2, 3, 4, and 7 days	108 J	VAS day 0, 1, 2, 3, 4, 7, 30, and 45	Yes
Qamruddin et al. (2018) [29]	single-blinded RCT (split mouth), placebo controlled	42: 26 F—16 M Age: 12–25	Fixed orthodontic treatment slot 0.022-inch (Extractions)	GaAlAs diode laser	940 nm 100 mW	7.5 J/cm^2, 5 points/side for 3 s. Only one dose	75 J per tooth	NRS. at consecutive 12 h intervals for 7 days	Yes

Table 1. *Cont.*

Articles	Study Design	Subject	Orthodontic Treatment	Device	Wavelength and Power	Dose	Total Energy	Pain Measurement	Statistically Significant Pain Reduction
Doshi-Mehta et al. (2012) [30]	RCT (split mouth)	20: 12 F—8 M Age: 12–23	Fixed orthodontic treatment slot 0.022-inch (Extraction)	GaAlAs diode laser	800 nm 0.7 mW	8 J (2 × 40 sec × 100 mW). 5 points/side Multiple doses: 0, 3, 7, and 14 days	8 J (2 × 40 s × 100 mW).	Visual pain scale at 1, 3, 30 days	Yes
Storniolo-Souza et al. (2020) [31]	double-blind, placebo controlled RCT (split mouth)	11 Age: ±14	Fixed appliances slot 0.022 × 0.028 inch (Extraction)	ArGaA l-Twin Laser	780 nm 40–70 mW	10–35 J/cm^2 5 points/side 10–20 s each Single monthly dose	4 J for mandible 9 J for the maxilla	VAS at12, 24, 48 and 72 h	No
Guram et al. (2018) [32]	RCT double-blind splint-mouth	20 12 F—8 M Age: 17–24	Fixed orthodontic treatment MBT bracket 0.022 inch (Extraction)	Ga-Al-As laser	810 nm 0.2 W	5 J/cm^2 8 spots for 10 s Multiple doses: each week for 21 days	Not indicated	Wong-Baker Faces Rating Scale days 1 to 7	Yes
Alam et al. (2019) [33]	Prospective clinical intervention	32 F > M Age: 14–25	Conventional backets and self-ligatin brackets slot 0.022 inch	GaAlAs laser	940 nm 100 mW	7.5 J/cm^2 5 points/side for 3 s each Only one dose	75 J per tooth	NRS At 4 h, 24 h, 3 d, and 7 d	Yes

RCT: Randomized Clinical Trial; VAS: Visual Analogic Scale; QST: Quantitative Sensory Testing; NRS: Numerical Rating Scale.

4. Discussion

For years, orthodontic treatment has been accompanied by pain, and this concept is considered natural and negligible compared to possible problems such as prolonged treatment time, periodontal problems and root resorption [21].

To date, more and more orthodontists are looking for a way to relieve patients' pain. There are several ways to decrease this discomfort such as using drugs, chewing plastic wafers or gum, a diet of softer foods and transcutaneous electrical stimulation [34].

Photobiomodulation is one of the latest methods to relieve orthodontic pain.

Although the mechanisms of action are not yet clear, photobiomodulation has been shown to have neural and anti-inflammatory periodontal regenerative properties. The use of diode laser in a continuous wave can result in significant pain reduction after tooth movement in the first three days [35].

4.1. Orthodontic Treatment

What is the purpose or goal of this section? Illustrate the different types of orthodontic equipment used in the studies analyzed in this literature review.

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? [8,21–27,29–32,36,37]

In this research, studies using elastomeric separators or bands, maxillary orthodontic expansion, invisible removal aligners or agenesis cases were excluded because the forces used and the perception of pain could be very different from a fixed orthodontic treatment.

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 [22,25–27,29–32,36,37].

4.2. Laser Procedures

What is the purpose or goal of this section? Illustrate the different laser procedures adopted in the studies analyzed in this literature review.

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? [23,25,27–29]

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 [27,29].

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 [27,29].

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].

In the Domìnguez and Velàsquez study, laser treatment was carried out during the final stage of orthodontic treatment, when stainless steel archwires 0.019×0.025 inch are used [28]. These results, in addition to the other studies, make us think that PBM is effective in modulating painful sensation at all stages of orthodontic treatment.

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

4.3. Dosages and Ways of Energy Distribution

What is the purpose or goal of this section? Illustrate the dosage and ways of energy distribution in photobiomodulation.

What new information does this session give? Low-level laser therapy usually uses the following parameters: a power density between 5 and 150 mW $\times$ 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? [33,37]

Low-level laser therapy usually uses the following parameters: a power density between 5 and 150 mW $\times$ 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 [37].

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 [33].

In the studies examined in this research, the wavelength is between 632 and 980 nm, the energy varies between 0.7 and 400 mW, and the total energy is not indicated in all studies. All studies indicating the amount of energy has within the efficacy window. These different protocols make it difficult to compare and quantify the beneficial effects on patients.

4.4. Statistically Significant Results

What is the purpose or goal of this section? Illustrate the results obtained by the 14 articles analyzed in this literature review.

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? [9,21–25,27–31,33]

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 [23,28–30].

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 [28,31].

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 [33].

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 [21,24,31].

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.

All articles used for this research agree on the onset of pain in about 2–4 h after the arch wire was activated, up to a peak at 24 h. Then, the painful sensation decreases and disappears within 7 days [21,24,27–29].

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

What is the purpose or goal of this section? Illustrate the different parameters used in the studies analyzed in this literature review.

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? [8,21,23,25–29,31,38]

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 [27,29].

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 [38].

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 [8,21,23,26,28,31]. 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.

4.6. New Perspectives wirh LED Devices in Orthodontics

What is the purpose or goal of this section? Propose LED technology as a new field of research in the field of photobiomodulation to reduce pain in fixed 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 $\times$ 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 $\times$ 3 cycles), with 1 min of rest between each cycle.

The results obtained with ATP38 are very interesting [10,11], they seem equivalent to those present in the literature with the use of diode lasers, in terms of pain, although for now they have been applied to different orthodontic techniques.

Unlike protocols offered with the use of a handpiece intended for manual use by operators, the ATP38 is able to evenly apply energy to all areas affected by orthodontic equipment, the maxillary and mandibular arches and the mandibular temporal joints, and in fact can be considered an “independent operator”.

5. Conclusions

This research shows that most authors observed that the reduction in pain in orthodontic fixed treatment cannot be attributed to placebo-based mechanisms. They said that laser therapy is effective in reducing painful sensation during different stages of fixed orthodontic treatment. Other authors showed that there were not statistically significant results in favor of photobiomodulation, but it is important to remember that they used different parameters, including technical specifications and application modes. In this regard, even just one parameter can influence the effect of PBM. Additionally, results depend also on the participants' individual variability.

To obtain generally valid studies, with consistent and reproducible results, it is necessary to standardize the different parameters used that are independent by operator performing the procedure.

LED seems to be as efficient as Laser in PBM protocols for pain management in orthodontics. However, the use of LED is less operator dependent, but more studies on laser technologies have been performed, especially in orthodontic fixed treatment. Hopefully, by suggesting the spread of devices similar to ATP38, the scientific validity of PBM research in orthodontics will increase.

It would be appropriate in the near future to define common research protocols in different universities with identical application parameters, which can lead to scientifically relevant and reproducible results, in order to be able to offer photobiomodulation in orthodontics, with both laser and PBM, as a fundamental device to reduce the invasiveness of orthodontic therapy.

Author Contributions: Conceptualization, G.C.; data curation, P.C.; methodology, P.C.; validation, G.C.; supervision, G.C.; writing—original draft, G.C. and I.C.; writing—review and editing, P.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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