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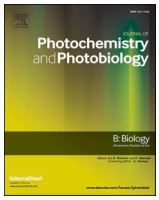

Comparative analysis of Laser and LED phototherapies pain control after insertion of elastomeric separators in orthodontics patients: Clinical trial

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ABSTRACT

The aim of this study was to evaluate the effectiveness of pain modulation following Laser or LED phototherapies during the process of tooth separation. This was a longitudinal randomized controlled clinical trial in four observational times carried out in 60 patients (15 males, 45 females, average 24.1 years old) who were randomly divided into three groups: G1 (LED, AsGaAl, λ850 ± 10 nm, 150 mW, 17 J/cm^2, 57 s per session), G2 (Laser, AsGaAl, λ780 nm, 70 mW, 20.0 J/cm^2, 240 s per session) and G3 (Non-irradiated Control). All patients were submitted to tooth separation using elastomeric separators. The pain level was measured by using a visual analogue scale (VAS) immediately after insertion (T1) of the elastic, at 48 (T2), 96 (T3) hours and 6 days (T4). It was observed an increase of the pain on the Control group from T1 to T2, with statistical significance. Pain levels in the LED and Laser groups were always significantly lower (<0.001), except for T1. According with the results of the present study it may be concluded that, either LED or Laser phototherapies, were effective in reducing the pain level after dental separation process when compared to the control group.

1. Introduction

The overall worldwide prevalence of dental malocclusion (Angle's class I, II and III) is high [1]. It is accepted that around 50% of total world population of children and adolescents have indication of orthodontic treatment [1,2]. These problems can affect not only facial aesthetics but several functions such as chewing, swallowing, and speaking and may lead to lower self-confidence causing difficulties in everyday life [3,4]. The initial procedures like elastic separators insertion to make possible band insertion in molars and the aligning process using flexible archwires to apply low forces could promote pain complaint by patients undergoing orthodontic treatment representing a problem for orthodontists and causes a lack of compliance with the treatment [5–11].

The hyperalgesia is an effect of the force application to the teeth which will cause stretching or compression of the periodontal ligament and will initiate a complex inflammatory process with the participation of inflammatory mediators such as histamine, prostaglandin, serotonin, and bradykinin [6–12]. The inflammatory process is essential to induce a process of remodeling characterized by selective bone resorption and deposition in the areas of compression and tension of the periodontal ligament, respectively [6–12].

Despite pain being a subjective individual sensorial perception and of difficult evaluation as several factors such as the emotional state, stress, gender, age, previous painful experiences, cognitive, environmental, and cultural influences, social factors, motivation and expectation for orthodontic treatment and intensity of applied force are some of the factors that may influence the level of the pain perceived by the patient [6–12].

Recently, a variety studies on pain management in orthodontic procedures such as elastic separators insertion, initial archwires and orthodontic band insertion, have shown that the understanding of the mechanisms of photobiomodulation and how it can modulate pain are still progressing. However, it seems to be out of question that both Lasers and LEDs can be used as a pain control method in orthodontics [13–34].

The reported beneficial effects of both Laser and LED phototherapies in the pain of orthodontic origin are related with to both an early release of mediators of the inflammatory response such as prostaglandins, interleukins, and β-endorphin; increased vasodilation and vascular

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neoformation; stimuli to mesenchymal cell differentiation, favoring an early resolution of the inflammation [13–34].

It was hypothesized that the use of either Laser or LED phototherapies could reduce pain in patients undergoing the insertion of elastic separators. Thus, the aim of this study was to evaluate the efficacy of Laser and LED phototherapies on the pain management during process of tooth separation in orthodontic patients [21].

2. Methods

2.1. Ethical Aspects

This case-control, quantitative and qualitative, longitudinal study was approved by the Ethics Committee of the School of Dentistry of the Federal University of Bahia (Proc. 34,159,014.30000.5024).

2.2. Patients

2.2.1. Sampling

Sixty adult individuals of both genders (45 Females/15 Males), aged between 20 and 30 years old (mean 24.1 years old), were selected among the patients of the Prof. José Martins Soares Édimo Center for Orthodontics and Dentofacial Orthopedics at the School of Dentistry of the Federal University of Bahia (UFBA). All patients were indicated for full orthodontic corrective treatment, requiring the installation of orthodontic bands with attachments on the molars. After signing a consent agreeing to participate in the trial, the selected patients entered the study. Sample calculation, with power of 99% with a significance level of 95% and a minimum difference of 5% between the groups was performed. Based on this, the recommended minimum sample size was seven individuals per group. To increase the power of the study, twenty patients per group were used, making the results potentially more consistent. During data collection, six patients of the control group were excluded, because of the use of analgesics. Thus, new patients were recruited to fulfill the sample requirements.

2.2.2. Patient Examination and Inclusion/Exclusion Criteria

A single examiner, who also performed all clinical procedures, selected the patients. The inclusion criteria for participating as volunteers in the study were: to be aged between 20 and 30 years old; all teeth down to the second molars must have erupted and have contact points; all subjects must sign a form of free and informed consent. The exclusion criteria were presence of systemic diseases, neurological or psychiatric disorders, and chronic pain; use of systemic medications (analgesics, antibiotics, anti-inflammatory drugs, antidepressants, and bisphosphonates); pathological conditions associated with teeth, gingiva or periodontium; presence of restorations on the proximal surfaces of molars and premolars, adjacent to the site where the elastomeric separators were inserted; refusal to participate in the study.

2.3. Methods

2.3.1. Grouping

Patients were randomly distributed into the following groups: Group 1 LED phototherapy for pain control - this group received LED application for pain control; Group 2 (Laser) - this group had Laser application for pain control and Group 3 Control had no irradiation. None of groups know the existence of the other, avoiding in this way some sort of bias. Participants were asked to make use of painkillers (Paracetamol, Tylenol®, Sanofi-Aventis Ltda. Pharmaceuticals, Suzano-SP, Brazil, 1 g every six hours, until the pain decrease) in case of pain. In this case, they were excluded from the study.

2.3.2. Clinical Procedures for Insertion of the Separating Elastics

After defining the group's distribution, the separating elastics were inserted with the aid of two dental floss segments, on the distal and mesial surfaces of the upper right first molar, according to literature recommendations [15,18,24]. The patients should verify if the separators remained in place, especially when performing oral hygiene. Then, they were asked to fill out a form that was designed to assess pain sensitivity after insertion of separators. Thus, patients received four cards with a Visual Analogue Scale (VAS) to determine the pain index, followed by phototherapy with LED or Laser.

2.3.3. Irradiation Protocol

The international safety standards recommended for the use of LED and Laser in clinical practice were respected. For this, specific goggles for each wavelength used were provided for both patients and the researcher. The irradiation protocols were started immediately after insertion of the elastics and repeated every 48-h until the sixth day [21].

In the present study, the LED device used was FisioLED (MMOptics, São Carlos, São Paulo, Brazil) (Fig. 3) with the following parameters: GaAsAl, $\lambda = 850 \pm 10$ nm, $P = 150$ mW, continuous wave, $\Phi = 0.5$ cm^2, ED = 17.0 J / cm^2, $t = 57$ s per session, 51 J/cm^2 per treatment (Table 1). The irradiation was performed in two points of 8.5 J/cm^2 each, one on the middle third of the root distally on the buccal aspect of first maxillary molar and another on the palatal aspect, medially, in the middle third of the root, totalizing a dose of 17 J/cm^2 per application, with exposure time of 57 s per session. This protocol was performed immediately after the insertion of the elastic separators and repeated after 48 and 96-h (Fig. 1 *a,b*).The laser device used was Twinflex Evolution® (MMOptics, São Carlos, São Paulo, Brazil) with the following parameters: GaAsAl, $\lambda = 780$ nm, $P = 70$ mW, continuous wave, $\Phi = 0.05$ cm^2, ED = 17.0 J/cm^2, $t = 240$ s per session, 51 J/cm^2 per treatment [13] (Table 1). The Laser irradiation occurred in the same points previously described for LED group (Fig. 1 *c,d*).

2.3.4. Pain Scoring

The patient pain perception after elastic separator insertion was measured using Visual Analogue Scale (VAS) seen on Fig. 2 [34,35]. After the clinical procedure, they were instructed to place a mark next to the score corresponding to the amount of pain they felt. After insertion of the elastic separators, the patient scored the VAS, and LED or Laser was then applied (T1). The patient returned within 48 and 72-h counted from the day of installation (T2 and T3, respectively) to re-score the pain scale. LED protocol was performed, as determined by Figueira et al. [21]. The elastic separators were removed on the 7th day after installation, when the patient scored the last VAS (T4) indicating the pain they felt on the period. At this time, LED or Laser were no longer applied. The control group was also given the same guidelines and performed the same procedures as the experimental group, but with no Laser or LED

Table 1
Summary of the LED and Laser parameters used on the study.

Parameters	LED
Wavelength (nm)	850 ± 10
Mode	CW
Spot of the probe (cm^2)	0.5
Power output (mW)	150
Irradiance (W/cm^2)	0.15
Exposure time (s, per session)	57
Exposure time (s, total treatment)	171
Energy density (J/cm^2, per session)	17
Energy density (J/cm^2, total treatment)	51
Parameters	Laser
Wavelength (nm)	780 ± 5
Mode	CW
Spot of the probe (cm^2)	0.05
Power output (mW)	70
Irradiance (W/cm^2)	0.07
Exposure time (s, per session)	240
Exposure time (s, total treatment)	960
Energy density (J/cm^2, per session)	17
Energy density (J/cm^2, total treatment)	51

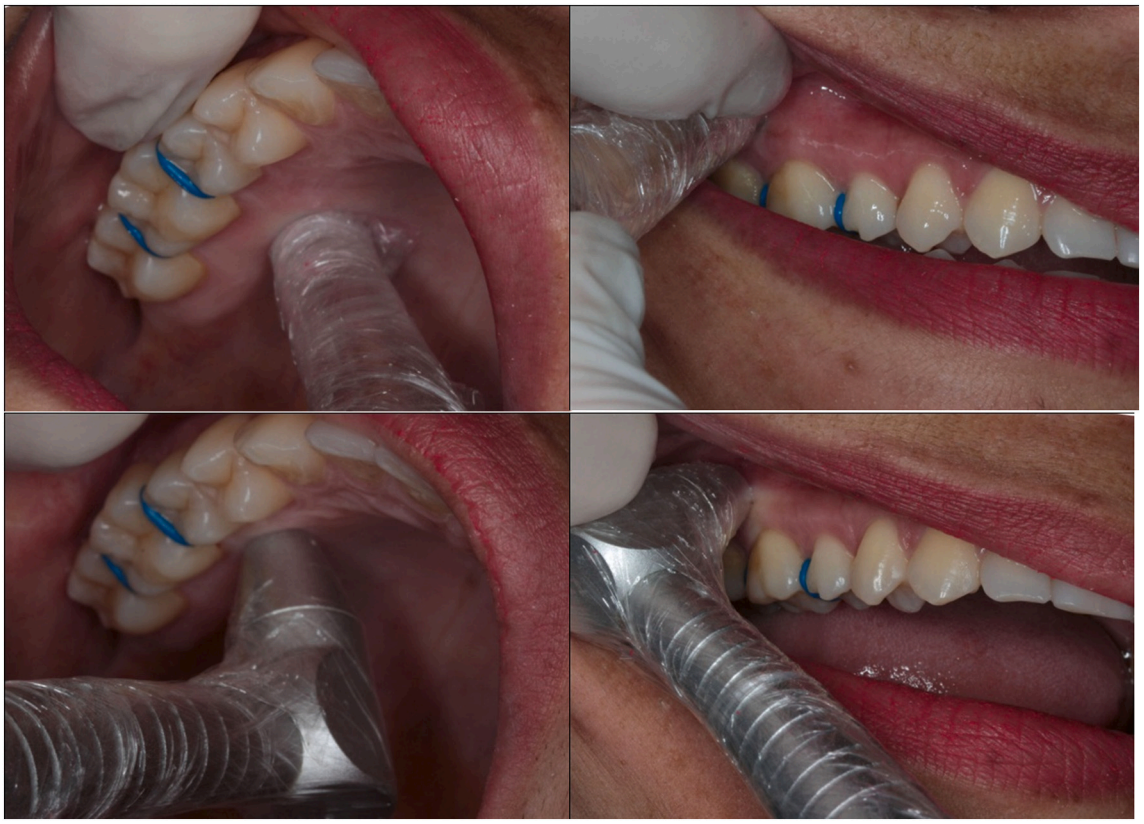

Fig. 1. Laser and LED irradiations protocols performed in palatal (a,c) and buccal (b,d) sites. Both Laser and LED were positioned perpendicular to the roots of the tooth and in contact with gingival tissue.

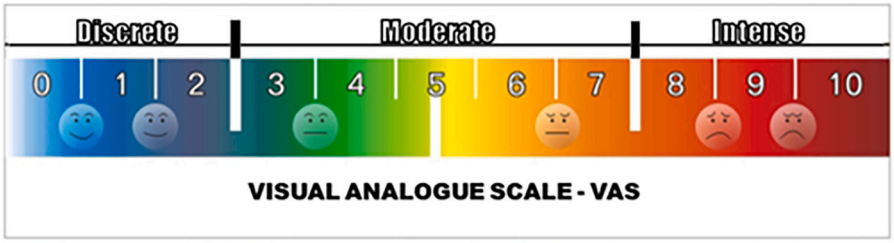

Fig. 2. Modified Visual analogue scale used to evaluate individual pain experienced by the patient through the experimental time.

application.

2.4. Statistical Analysis

Group sample sizes of 20 individuals achieve 91.123% power to reject the null hypothesis of equal means when the population means difference was 2 with standard deviations of 1.9 for group 1 and 1.8 for group 2, and with a significance level (alpha) of 0.05 using a two-sided sample unequal-variance *t*-test. The data were tabulated in the Microsoft Office Excel 2007 program, and statistical analysis was performed with R Core Team software, 3.3.1–2016 (A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria). Initially, a descriptive analysis of the results (median and quartiles) was carried out to characterize the sample studied. To verify the existence of significant differences in pain level between the different experimental times, in each group Friedman test was used and between groups Kruskal-Wallis was used. When necessary, the posteriori Dunn test (adjusted for multiple comparisons) was applied. The significance level adopted for this study was that of 5%.

3. Results

Sixty-six patients from the Ambulatory of the Center for Orthodontics and Facial Orthopedics Prof. José Édimo Soares Martins, Faculty of Dentistry - UFBA, had participated of this study. Six individuals from Control group were excluded due to the use of analgesics for pain relief. Total sample was composed by sixty patients, characterized by forty-five (75%) females and fifteen (25%) males with average age of 24.1 years old.

Table 2 describes the measurements of pain at each time (median and quartiles) in the groups and demonstrates an intergroup analysis. It was verified that only in the control group an increase of the pain from T1 to T2 could be observed, with statistical significance. However, it decreased after 96-h and reached its lowest score after 144-h (six days) in all groups. The comparison of pain levels from T2 (48-h) to T3 (96-h) and for T3 to T4 (144-h) was statistically significant in both experimental groups. In the control group, there was no statistically significant difference between T1 and T4 alone ($p > 0.05$). Table 2 and Fig. 3 shows that pain levels in the LED and Laser groups were always lower and statistically significant (<0.001) than on the Control group, except for

Table 2
Intra and intergroup analysis of pain levels at different times and *p*-values.

	VAS LED		VAS Laser		VAS Control	
	Median	q1-q3	Median	q1-q3	Median	p-value
Base	1.00	0–2	2.00	0–3	2.00	0.325
48 h	3.00[a]	0–4	3.00	1–6	8.50[b]	<0.001*
96 h	0.00 [a]	0–1	0.00	0–2	4.00[b]	<0.001*
144 h	0.00 [a]	00	0.00	0–0	1.00[b]	<0.001*
p-value	<0.001		<0.001		<0.001	

* The statistical difference refers to the groups LED - LASER X Control. There are no statistically significant differences between the groups LED and Laser. a,b means significative differences within the same group within the different times 48, 96 and 144-h.

T1, when the separator was inserted.

4. Discussion

Despite the recent evolution of several orthodontic procedures, pain remains as the major complaint of patients undergoing orthodontic treatment [5–12]. The orthodontic movement of tooth is based on the application of a "load-force" in specially designed devices which are positioned at specific areas of interest [5]. The use of these apparatuses produces either mechanical compression or tension on the periodontal ligament, blood vessels and bone caused by the tooth dislocation in the alveolus [5–12]. Both compression and tension cause the stimulation of cells and tissues and are associated to changes on blood flow or even the complete stop of blood circulation in these areas (e.g., when a non-optimal force is applied) [5–12]. In response to this effect, a complex pro-inflammatory cascade is initiated with liberation of cytokines including histamine, bradykinin, prostaglandins, and others [5–16].

These biological responses cause a so-called aseptic inflammation which results in the stimulation of C-nerve and A-delta nerve fibers triggering the pain symptom [5–16]. Both intensity and duration of the stimuli are variable and dependent on both the intensity of the force applied and on the individual biological response. However, in general, pain symptoms are most normally observed during early hours following the application of the forces [5–20].

Visual Analogue Scale (VAS) was chosen as instrument for pain evaluation. VAS is reliable and validated technique in scientific community to be used in assess of acute and chronic pain [34,35]. Despite being a subjective method where the individual itself should mark the intensity of their pain on a scale from 0 to 10, it seems to demonstrate faithfully the pain experienced by the patients and is well acceptable and used on pain studies worldwide [21–29].

All patients not included in the quantitative data analysis carried out on the present investigation were excluded by a single exclusion criterion: the use of analgesics or anti-inflammatories and, coincidentally, all the excluded ones were from the control group.

It is well known that pain caused by orthodontic treatment usually reaches its peak after 24–48-h with a gradual decline over the following week if any pain treatment is used [5–12,14–33]. The level pain experienced by the patient causes lack of commitment by them and even the interruption of the treatment at early stages [5–12]. In the present study, it was verified that, in all groups, higher pain scores occurred 48-h after the insertion of the elastic separator and decreased significantly until the sixth day (Fig. 3) in a similar way as previously reported in the literature [15,17,18,21–29].

Laser and more recently LED phototherapies have been successfully used for the biomodulation of several conditions in Dentistry, such as on bone and soft tissue repair as well in the management of both acute and chronic pain of a wide variety of etiologies [13,14,20,31,36] as well as for reducing the extreme discomfort of oral mucositis caused by either chemotherapy or radiotherapy [37].

Despite some models tried to explain how phototherapies-induced analgesia occurs, the full mechanism is still under investigation [13–15,17–33,37–43] However, is well-known that axonal depolarization, decrease production of acute inflammatory mediators (IL1-B, IL-6, TNF- α), vasodilation and vascular neoformation, and also systemic effects by improved capacity of immune system are some of the effects in pain management to be expected after photobiomodulation, decreasing the pain perception period and providing a less intense inflammation [13–15,17–33,37–43]. The pain modulation is, undoubtedly, a great indication of the use of Laser or LED phototherapies in this matter, besides being a simple and painless method of therapy with no side effects and contraindications and can suppress the use of analgesics and anti-inflammatory medications [13–15,17–33,37–43].

Phototherapies are widely used to pain management after orthodontic procedures like the insertion of elastic separators and arch-wire activations [21–33]. Despites the successfully use of Laser phototherapies [22–35], LED irradiation protocols [21] have been poorly reported in the literature. One must consider that LEDs are more affordable, can be designed with a wide range of shapes and are more energy efficient than lasers in general, representing a reliable treatment option for Orthodontists [44,45]. In this study, we have demonstrated that LED phototherapy protocol can be used with no statistically difference with laser phototherapy protocol for pain management after elastic separators insertion. Important to notice that all patients not included in the quantitative data analysis carried out on the present investigation were excluded by a single exclusion criterion: the use of analgesics or anti-inflammatories and, coincidentally, all the excluded ones were from the control group. This finding does support the evidence that, both Laser and LED irradiation, did prevent the use of analgesics.

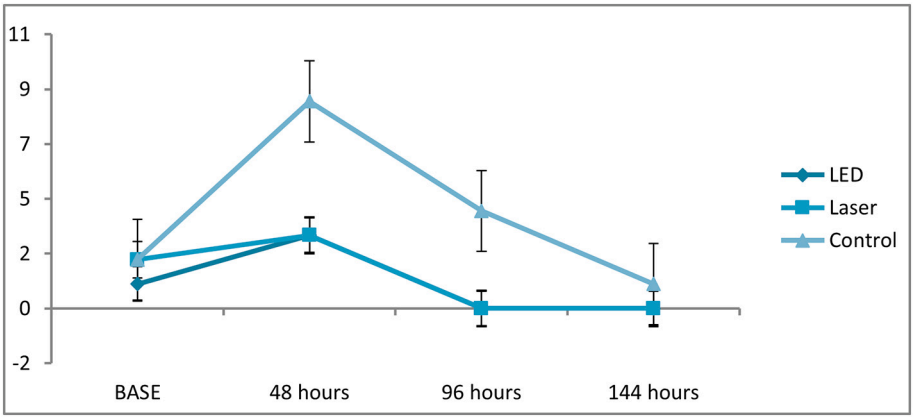

Fig. 3. Pain levels in the LED, Laser and Control groups.

A main problem in the use of phototherapies for pain management is the establishment of an effective protocol of irradiation or, at least, a safe window of parameters that could be used with beneficial clinical outcomes [21–33,36–43]. In studies that recorded more positive outcomes, there is no consistent uses of wavelength, dose (J), radiant exposure (J/cm^2), irradiance (W/cm^2), spot size, average power output, time of irradiation or location of the points of application, suggesting that exists many possible protocols to manage pain with phototherapies with satisfactory results.

Most studies involving pain management in Orthodontics found in the literature have used Laser phototherapy [15,17–19,22–33]. The wavelengths used were variable and ranged from λ632 to λ910 nm [15,17–19,21–33]. According to two systematic reviews caried out by Li et al. 2015 [17] ($n = 11$) and Ren et al. 2015 [18] ($n = 14$) the most used wavelengths were in the infrared band (ranging from λ780 to λ910 nm) while the red band was less used (ranging from λ632.8 to λ670 nm – 4 studies) [24–27]. Of these papers used in both reviews, only Angelieri et al. 2011 [30] and ours used λ780 nm. In relation to LED phototherapy, doses ranged from 4 J/cm^2 [25] to 8 J/cm^2 [21]. In the present study we used 17 J/cm^2 that is close to the ones used by Eslamian et al. 2014 [28] (20 J/cm^2), Heravi et al. 2014 [31] (21.4 J/cm^2) as well as our previous reports [13,21,32,33]. Only one study reported [24] on both reviews [17,18] did not use VAS as an evaluation method ($n = 35/34$).

Given the evident multiphasic response of biological tissues to the light, it is evident that the dosimetry associated with pain management in Orthodontics is relatively high in comparison to the treatment of other painful conditions [13,14,20,32,36,42,37]. Previous clinical trials [21–33] that showed best outcomes for pain relief when using phototherapies in multiple points (e.g., at the apices and around the crown of the tooth) applied energies ranging from 5 to 20 J/tooth [21–33]. This evidence suggests that a safe range for therapeutic exposure shall be kept between 10 and 30 J/cm^2 using low-power output and an irradiance of less than 500 m W/cm^2. On the present study an energy density of 17 J/cm^2 was used for both Laser and LED phototherapies with similar outcomes for them.

In the present study, no significant differences were observed on pain scores between all groups at the baseline time (T1 – immediately after the insertion of the elastic separators), this could be explained by the fact that first evaluation time (T1) was immediately after the insertion of the elastic separators, that gave no time for the phototherapies or any type of treatment to cause relief of the pain caused by the mechanical compression of the periodontal ligament [5–12,21]. On the other hand, statistically significant differences were seen between the Control and Laser/LED photobiomodulation groups at T2 (48-h), T3 (96-h) and T4 (144-h) after insertion procedure. There was no significant difference between the two light sources at these times.

On this way, our findings have shown that both Laser and LED phototherapies are effective on pain modulation after the insertion of elastomeric separators in orthodontic patients, decreasing the pain scores in all times, except immediately after the procedure. Due to the large number of possible protocols, more clinical studies are needed to evaluate the best approach for everyone.

5. Conclusion

It can be concluded that with the parameters used on this study, a favorable effect of LED (λ850) nm and Laser (λ780) nm phototherapies could be observed on the pain relief during orthodontic tooth separation process, evidencing a statistically significant decrease in the level of pain when compared to the control group. It was also observed that both phototherapies had similar performances on pain modulation. Also, based on our data, methodology and phototherapy protocol used in this study we can assume that LED light can replace the Laser for pain relief in Orthodontics due to its advantages such as portability, reduced cost, besides presenting less time of irradiation.

Author Statement

We certify that this manuscript is original work and that it has not been published in any other medium and it is not under consideration for publication in any other journal. Furthermore, we the authors are liable for its content and for having contributed to the conception, design and implementation of the work, data analysis and data interpretation, and for having participated in writing and reviewing the text, as well as approving the final version submitted. In case of its acceptance, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. The manuscript was checked for spelling and grammar. I also acknowledge that potential for conflict of interest does exist, as specified in the appropriate section in the manuscript.

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Availability of Data and Material

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Code Availability

Not Applicable.

Ethics Approval

This case-control, quantitative and qualitative, longitudinal study was approved by the Ethics Committee of the School of Dentistry of the Federal University of Bahia (Proc. 34159014.30000.5024).

Consent to Participate

According to Brazilian regulations all participant who agreed to entry the study signed a written informed consent.

Consent for Publication

Not Applicable.

CRediT authorship contribution statement

M.C.S.M. Bezerra: Investigation. **F.A.L. Habib:** Conceptualization, Investigation, Supervision, Writing – original draft, Writing – review & editing. **L.G.P. Soares:** Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **M.C. Vitale:** Writing – original draft, Writing – review & editing. **A.L.B. Pinheiro:** Conceptualization, Validation, Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

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