Asian Journal of Dental Sciences

5(4): 178-187, 2022; Article no.AJDS.92707

The Effectiveness of LLLT on Orthodontic Tooth Movement Acceleration: A Systematic Review of Human Studies

Karima Dabbar [aω*], Wiem Ben Amor [a#], Ghassen Kallel [aω], Ines Dallel [a†], Samir Tobji [a†] and Adel Ben Amor [a†]

[a] Department of Orthodontics, University of Monastir, 5000, Monastir, Tunisia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/92707

Systematic Review Article

Received 13 August 2022
Accepted 17 October 2022
Published 07 November 2022

ABSTRACT

Background: Low level laser therapy (LLLT) has been verified efficacious in pain reduction. But the research results remain unclear and debatable in terms of orthodontic tooth movement (OTM) acceleration. Therefore, this systematic review was conducted to scrutinize the ability of photobiomodulation to increase the rate of orthodontic tooth movement.
Methods: A total of three databases were searched until July 2022. Controlled randomized clinical studies assessing the effect of photobiomodulation on the rate of orthodontic tooth movement published during the last 10 years in English were eligible to be selected. Study selection and data extraction were undertaken independently by two reviewers. Risk-of-bias (RoB) assessment was evaluated using Grade guidelines. The reporting of this review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.
Results: A total of nine studies were identified for inclusion among 95 articles. A metanalysis could not be performed due to the heterogenity of the included studies. Six studies found a positive correlation between LLLT and acceleration of tooth movement. However, three trials found no significant difference between control and test group.
Conclusions: Based on the current moderate evidence, photobiomodulation could be an effective method on tooth movement acceleration. More well-designed randomized controlled trials are called for to obtain more clinically significant conclusions.

[ω] Doctor;
[#] Assistant Professor;
[†] Professor;
**Corresponding author: Email: dabarkarima@gmail.com;*

Keywords: Photobiomodulation; LLLT; acceleration; tooth movement.

1. INTRODUCTION

Orthodontic treatment is estimated to last 20 months [1], but such duration would be longer seeing the complexity of the case, the technical difficulties and several other reasons. This lengthened duration is one of the major drawbacks of the treatment. It may reduce the patient cooperation and increase the risk of complications including root resorption, periodontal disease, white spots, decalcification, temporomandibular dysfunction and pain [2]. Furthermore, patients have become increasingly demanding a short term treatment because of esthetic urges. Therefore, numerous methods have been developped in order to satisfy this need. Surgical techniques such as decortication, piezocision, and osteoperforation had proven their success in accelerating tooth movement by stimulating bone remodeling. The alveolar corticotomy remains the gold standard [3]. Nevertheless, the complications associated to these procedures such as pain and discomfort limited their use [4]. Later, different physical approaches were suggested as an alternative to traditional appraoches in order to limit its invasiveness. Among those non surgical procedures, photobiomodulation is a non-invasive method of applying a low intensity laser to stimulate cell response. It is easy to use, localisated, unlike pharmacological methods avoided by clinicians because of their probable systemic effects [5]. The previous characteristics facilitated its acceptance by the orthodontist and his patient. The parameters of this light therapy are well defined to stimulate a biological reaction without causing any side effects. It uses a laser light within the red to near-infrared range (wavelengths is between 600 and 1070 nm). [6] Several previous in vitro studies examinated the efficacity of LLLT and the results have shown an accelerating bone remodeling effect. [7] These studies have used an irradiation doses that cannot be applied clinically.

In this context, the present systematic review was undertaken in order to improve our knowledge concerning the effects of LLLT on orthodontic tooth movement rate. It is structured by four main sections : Introduction, Materials and Methods, Results, and Discussion (IMRaD structure).

2. MATERIELS AND METHODS

2.1 Eligibility Criteria

The PICOS (population, intervention, comparison, outcome, study design) format was used to formulate the clinical question with defined inclusion and exclusion criteria (Table 1).

All articles included in this systematic review met the following criteria.

2.2 Information Sources and Search

Two reviewers independently conducted a comprehensive search using a combination of controlled vocabulary (MeSH) and free text terms. PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), and Sciences Direct were searched from January 2012 to June 2022. Only english articles were included. Keywords used in search were : ‘’LLLT’’, ‘’Orthodontics’’, ‘’Acceleration’’, ‘’Movement’’, ‘’Photobiomodulation’’.

Table 1. Eligibility criteria

Domains	Inclusion Criteria	Exclusion Criteria
Participants	Subject with permanent dentition who require orthodontic treatment	Subject with systemic diseases, syndromes, dental pathologies. Patients had previous orthodontic treatment, animal studies
Intervention	Use of photobiomodulation LLLT	Studies using vibrating appliance only
Comparaison	Orthodontic treatment without any acceleration methods.	
Outcome	Acceleration of tooth movement	
Study design	RCT	Retrospective studies, case reports, comments, letters to the editor, narrative reviews.

RCT : Randomized Controlled Trial

Table 2. Details of the database search

Database	Search Strategy
Pubmed	("Low-Level Light Therapy" [Mesh:NoExp]) AND "Orthodontics" [Mesh]) AND "Acceleration" [Mesh]
Cochrane	photobiomodulation AND orthodonticAND Movement AND acceleration LLLT AND movement AND orthodontic AND acceleration
Sciences Direct	photobiomodulation AND movement AND orthodontic AND acceleration LLLT AND movement AND orthodontic AND acceleration

2.3 Study Selection

The study selection process was done independently and in duplicate. All relevant articles were imported into Zotero, a bibliography generator. First, duplicate articles were removed. Secondly, the titles and the abstracts were assessed for eligibility. Full-text reports were considered for articles that seemed to have met the inclusion criteria. Finally, relevant articles were analysed thoroughly.

2.4 Data Collection Process and Items

Data was extracted from the selected articles in this study using a predefined standardized form by two reviewers independently. The following items were considered relevant and thus collected : author, year, number of participants, type of treatment, duration of laser application, outcome and author conclusion. Any doubt or disagreement between the two reviewers was resolved by discussion.

2.5 Risk of Bias of Individual Studies

The risk of bias (RoB) of all relevant studies was assessed by Grade Guidelines. This tool is designed for methodological evaluation of randomized controlled trials. It judges each study based on nine items, each one can be answered by ‘Yes’, when clearly done, by ‘No’, when clearly not done, and by ‘Uncertain’, when the item is inaccurate [8]. The possible range of Grade scores is from 0 to 9. Each study that scored higher than 6 was described as high-quality study, while those with a score less than 5 indicated a high risk of biais and those with a score between 5 and 6 were defined as moderate quality.

3. RESULTS

3.1 Study Selection

The global outcome of the electronic search as well as the articles’ selection process were illustrated in the PRISMA flow diagram in accordance with the PRISMA guidelines. A total of 95 studies were initially identified through databases searching. After removing duplicates, 70 studies remained and only 9 overcame the reading of titles and abstracts. Eventually, after an accurate study of the full texts, the same 9 articles were included in the qualitative analysis.

3.2 Study Characteristics

Among the nine included studies, six ones used a split-mouth design and three used a two parallel group design. Two types of tooth movement were investigated in those studies : canine retraction and lower incisors alignment. All the RCTs used a high frequent application of LLLT except one trial which compared two frequencies of laser application. The wavelengths of light used for the experimental sides ranged from 618 nm to 980 nm.

3.3 Data Extraction and Synthesis

The nine articles included in this systematic review and the data extracted from each study are shown in Table 3.

3.4 Risk of Bias in Included Studies

The quality of evidence of the included studies was evaluated by the Grade guidelines tool. Three studies [9,12,13] scored 7, indicated a high quality study. The four articles [14,15,16,17] that scored between 5 and 6 indicated a moderate quality, while two articles [10,11] were evaluated as low quality.

In all included studies, it was not possible to perform blinding during the experimental period. This was due to the presence of the barrier film on the test side of the appliance that was plainly visible to both the operator and the patient.

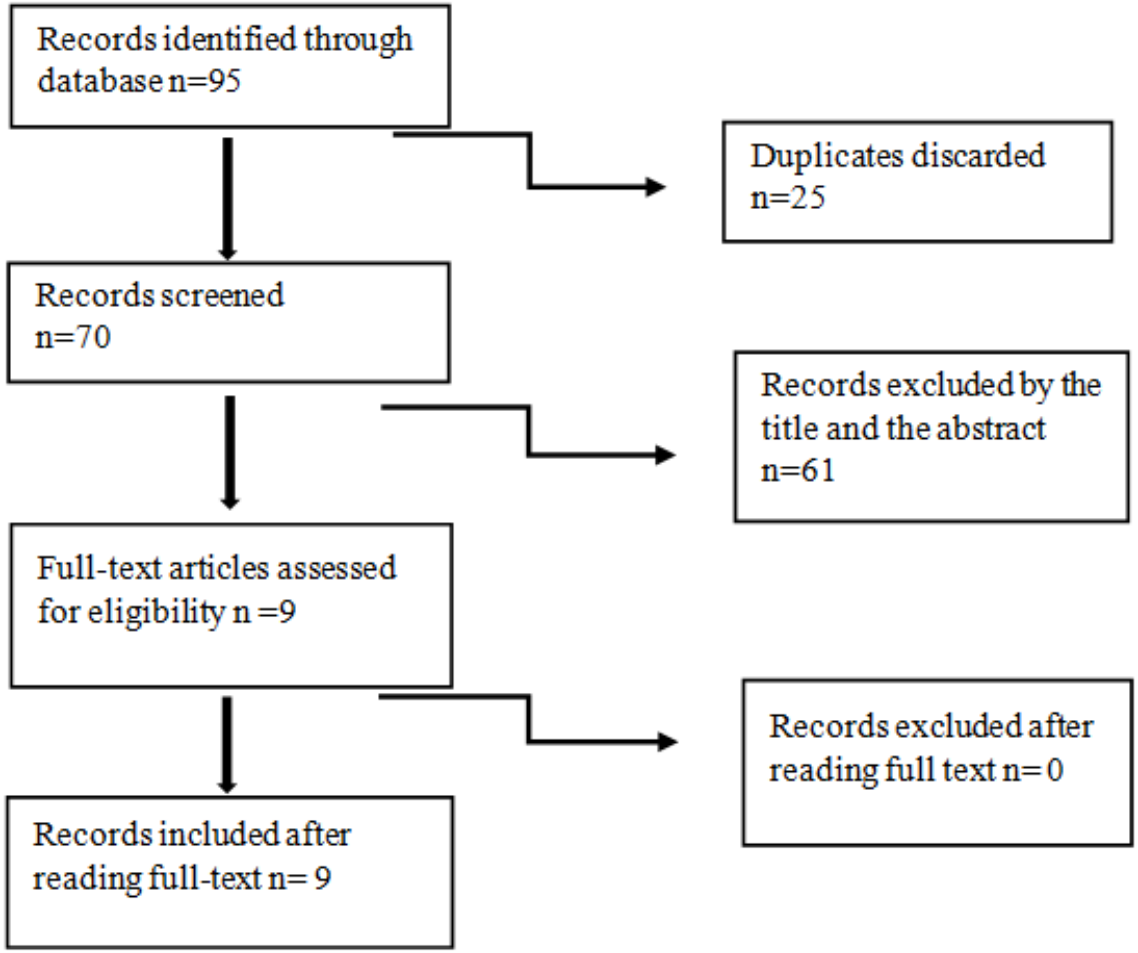

Fig. 1. Flow chart according to the PRISMA statement

Table 3. Overview of included studies

Author	Year	Study design	No of participants	Type of treatment	Laser device	Duration of laser application	Outcome	Conclusion
Safa Al-Shafi [9]	2021	Split mouth	20 (10M, 10F)	maxillary canine distalization	LED device (orthopulse, 850 nm wavelength)	5 minute/day	The mean space closures of the maxillary canines were comparable between right and left sides.	A daily 5 min application of photobiomodulation seems inefficient in the acceleration of canine distalization.
Mohammad Moaffak A. AlSayed Hasan [10]	2017	Two arm	26 (13 per group)	leveling and alignment	Diode laser (830 nm wavelenght)	1 minute/tooth	The alignment treatment time was significantly shorter in the tested group compared with the control (P< .001).	LLLT is an effective method for accelerating orthodontic tooth movement.
FarahY. Eid [11]	2022	Two arm	20 F	maxillary canine retraction	Diode laser (980 nm wavelenght)	8 seconds	Significant increase in the canine retraction rate on the laser sides of groups A and B, in comparison with the control sides ($p < 0.05$). No significant differences reported between the laser sides in both groups A and B.	LLLT can effectively accelerate tooth movement, with both frequent and less frequent applications.
Abdullah Ekizer [12]	2016	Split mouth	20 (13 F, 7 M).	maxillary canine	LED device (osseopulse,618	20 minutes per day	Significant differences were	Photobiomodulation had the potential of

Author	Year	Study design	No of participants	Type of treatment	Laser device	Duration of laser application	Outcome	Conclusion
				distalization	nm wavelenght)	during 21 days.	observed between test and control group.	accelerating orthodontic tooth movement.
Tharwat Osman El Shehawy [13]	2020	Two arm	30 (18 F, 12 M)	leveling and alignment of mandibular incisors.	Diode laser (635 nm wavelenght)	10 seconds at 10 points	The alignment`s rate showed no significant differences between groups. (p>0.05)	Laser accelerator effect is negligible.
Yasmine Khaled Abdel Ghaffar [14]	2022	Split mouth	32 F	leveling and alignment of mandibular anterior crowding	Diode laser (940 $_{+-}$ 10 nm wavelength)	Not Mentioned	The mean time for alignment was significantly lower in the laser group.	LLLT has a potential for acceleration of anterior segment alignment.
Alessandra Impellizzeri [15]	2020	Split mouth	3 (2 F, 1 M)	Canine retraction	Diode laser (650 nm and 910 nm wavelenght)	session treatment durations of 2–4 minutes	A statistically significant difference ($p < 0.05$) was found between the average speed of the irradiated canines and the control canines.	The laser application with the parameters set, was found to be a tool capable of accelerating the distal displacement of canines.
Junyi Zheng [16]	2021	Split mouth	12	Canine retraction	Diode laser (810 nm wavelength)	40 seconds on 4 points around the canine.	The cumulative tooth movement over 28 days was significantly higher in the laser group than in the control group.	With the parameter settings used in this study, LLLT could lead to changes in bone metabolism, which could accelerate orthodontic tooth movement.

Author	Year	Study design	No of participants	Type of treatment	Laser device	Duration of laser application	Outcome	Conclusion
Alissa Maria Varella [17]	2018	Split mouth	10 (6 F, 4 M)	Canine distalization	Diode laser (940nm wavelength)	10 seconds on 10 points aroud the canine.	Cumulative tooth movements over an 8-week experimental period were greater for the experimental canines compared with the control canines.	Application of LLLT increased the levels of IL-1b in gingival crevicular fluid and accelerated orthodontic tooth movement.

F : female, M : male.

Table 4. RoB assessment of the included studies

Item	9	10	11	12	13	14	15	16	17
random sequence generation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
allocation concealment	Yes	Yes	Yes	Yes	Yes	Yes	Uncertain	Yes	Yes
blinding of participants and personnel	No	No	No	No	No	No	No	No	No
blinding of outcome assessment	Yes	No	Uncertain	Yes	Yes	Yes	Uncertain	Uncertain	Uncertain
objective outcome	Yes	Uncertain	Uncertain	Yes	Yes	Uncertain	Yes	Yes	Yes
more than 80% of trial participants included in the analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
data reported consistently for the outcome of interest reporting	Yes	Uncertain	Uncertain	Yes	Yes	Yes	Yes	Uncertain	Yes
No other biases reported	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain
Did the trials end as scheduled	Yes	Uncertain	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Score	7	3	4	7	7	6	5	5	6

4. DISCUSSION

4.1 Summary of Evidence

Recently, there has been an increased interest in research focused on tooth movement acceleration. In order to realize this objective, several procedures have been suggested and experimented, such as surgical methods, which ended up being successful [18]. However, they are avoided by both pratician and patient due to its invasiveness [19]. Physical interventions were suggested with the aim of reducing negative effects. On this systematic review, we focused on one of the recently introduced devices for movement acceleration using LLLT.

According to the results of this review, conflicting conclusions regarding the effectiveness of photobiomodulation were demonstrated. Nine RCTs were included, comprising 173 subjects. No study was considered as having a low risk of bias. Seven of these trials showed a positive correlation between LLLT and accelerated orthodontic tooth movement. These results are consistent with those of da Silva Sousa study's [19], that highlighted the efficacy of light emitting devices on canine retraction without causing any side effects. In addition, a systematic review conducted on 2020 by Maciej Jedlinski [20] explored the literature on the benefits of photobiomodulation as an adjuvant to reduce treatment duration. It showed that laser therapy had positive effect only in the short-term, without succeeding in reaching consensus on the parameters for using LLLT to reduce treatment time. Meanwhile, there is a significant lack of studies looking at long-term effects.

In disagreement with these findings. Al-Shafi et al. [9] showed no benefits of photobiomodulation. This was the first trial to study intraoral laser application using the OrthoPulse device. These results were similar to those reported by El Shehawy et al. In their study [13], the suggested laser application parameters failed to facilitate the alignment of the mandibular incisors. Furthermore, Goulart et al. [21] found that higher laser doses might even inhibit the orthodontic movement. It was concluded that laser effect was very dose dependent.

In our review, three trials [17,14,11] assessed the effects of Laser application on biological markers by measuring the levels of IL-1β in gingival crevicular fluid. Two studies, Varella [17] and FarahY Eid [11] found significantly higher levels of IL-1b in the experimental canines compared with the control canines at all time intervals. This might explain the acceleration of orthodontic movement by the importance of the alveolar resorption phase. As known, this interleukin is the prototypic pro-inflammatory cytokine which plays significant role in the recruitment and activation of osteoclasts. In contrast, there were no significant differences observed in the IL-1b levels between the test and the control sides in Ekizer's clinical trial.

For the evaluation of pain, in the present review, Yasmine Khaled, unlike several previous studies which reported the benefits of LLLT on pain reduction, showed no statistically significant difference in pain scores between the test and control group except for the fifth day of treatment.

As a conclusion, the variability of the results could be explained by the variability of the used laser parameters (wavelength, power, irradiance), the frequency of application of the irradiations and other factors, such as individual tissue response and treatment protocols. Therefore, future clinical trials should be carried out to explore the optimal protocols and the appropriate dose of laser for accelerating movement.

In this review, we focused on Low level laser therapy. In contrast, there are multiple other recent techniques such as gene therapy that suggested RANKL transfer attracting the attention of researchers nowadays. They do deserve more advanced experimentation.

4.2 Limitations

As all systematic reviews, there are some limitations to this one. In the first place, the exclusion of articles published in other languages than English could not be ignored. Second, no studiy had evaluated the effect of LLLT throughout the course of treatment. All studies were interested in a single step where canine retraction was the most studied movement. Third, the relationship between LLLT and OTM acceleration was not explained and remains undetermined due to the lack of histological and biological studies. Last but not least, this systematic review was not registered in PROSPERO that might be an additional limitation.

5. CONCLUSION

The present systematic review investigated the efficacy of LLLT for accelerating OTM. According

to the findings of the included studies, moderate-quality evidence suggested that photobiomodulation is effective in promoting tooth movement, at least in the short term. There is clearly more work to be performed to confirm or refute this review's results.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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