

Systematic Review

The effectiveness of LLLT on orthodontic tooth movement acceleration : A systematic review of human studies

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 3 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. Reporting of this review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Results: A total of 9 studies were identified for inclusion among 95 articles. A meta-analysis could not be performed due to the heterogeneity 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.

Key words : photobiomodulation, LLLT, acceleration, tooth movement

1. INTRODUCTION :

Orthodontic treatment is estimated to last 20 months [1], but the 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 could 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 developed in order to satisfy this need. Surgical techniques such as decortication, piezosurgery, and osteotomy 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 approaches in order to limit its invasiveness. Among those nonsurgical procedures, photobiomodulation is a non-invasive method of applying a low intensity laser to stimulate cell response. It is easy to use, localised, counter to pharmacological methods avoided by clinicians because of their probable systemic effects [5]. These 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 examined the efficacy 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.

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
Comparison	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.

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 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 orthodontic AND Movement AND acceleration LLLT AND movement AND orthodontic AND acceleration
SciencesDirect	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 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

imprecise [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 bias 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 are 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 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 2 frequencies of laser application. The wavelengths of light used for the experimental sides ranged from 618 nm to 980 nm.

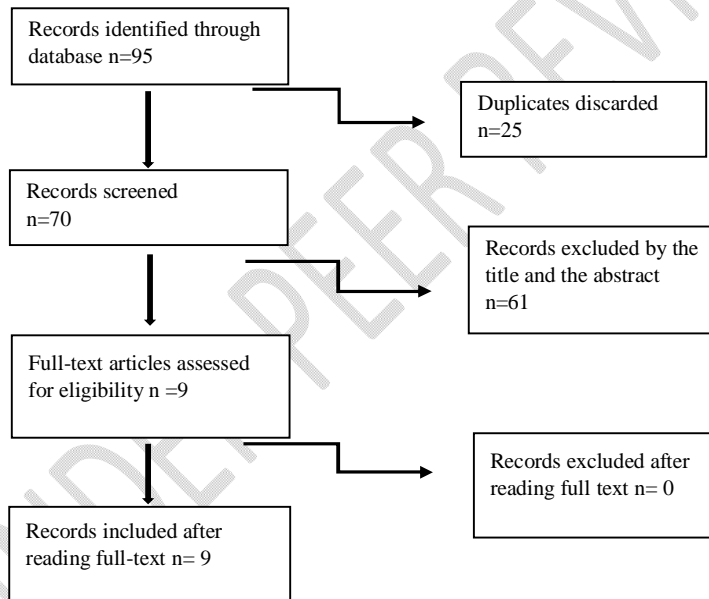


Fig 1 : Flow chart according to the PRISMA statement

3.3. Data extraction and synthesis :

The nine articles included in this SR and the data extracted from each study are shown in Table 2.

Table 3. Overview of included studies.

Author	Year	Study design	No of participants	Type of treatment	Duration of laser application	Outcome	Conclusion
Safa Al-Shafi [9]	20	Split mouth	20 patients (10M, 10F)	maxillary canine distalization	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 patients (13 per group)	leveling and alignment	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.
Farah Y. Eid [11]	2022	Two arm	20 F patients	maxillary canine retraction	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 patients (13 F, 7 M).	maxillary canine distalization	20 minutes per day during 21 days.	Significant differences were observed between test and control group.	Photobiomodulation had the potential of accelerating orthodontic tooth movement.
Tharwat Osman El Shehawey [13]	2020	Two arm	30 patients (18 F, 12 M)	leveling and alignment of mandibular incisors.	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 patients F	leveling and alignment of mandibular anterior crowding	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 patients (2 F, 1 M)	Canine retraction	session treatment durations of 2–4 minutes	Statistically significant difference (p < 0.05) was found between the average speed of their irradiated canines and the control canines.	The laser application with the parameters set, was found to be a tool capable of statistically significantly accelerating the distal displacement of canines.
Junyi Zheng [16]	2021	Split mouth	12 patients	Canine retraction	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.
Alissa Maria Varella [17]	2018	Split mouth	10 patients (6 F, 4 M)	Canine distalization	10 seconds on 10 points around the canine.	Cumulative tooth movements over an 8-week experimental period were greater for the experimental canines compared with	Application of LLLT increased the levels of IL-1b in gingival crevicular fluid and accelerated orthodontic

						the control canines.	tooth movement.
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F : female, M : male.

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.

The RoB assessment of the included studies is presented in Table 4.

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 goal, several procedures have been suggested and experimented, such as surgical methods, which ended up being successful [18]. However, they are avoided by both practitioner 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's study [19], that highlighted the efficacy of light-emitting devices on canine retraction without causing any side effects. In addition, a systematic review conducted in 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 a 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 Shehawey 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-1 β in gingival crevicular fluid. Two studies, Varella [17] and Farah Y Eid [11] found significantly higher levels of IL-1 β 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 a significant role in the recruitment and activation of osteoclasts. In contrast, no significant differences were observed in the IL-1 β 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 a LED laser for accelerating movement.

In this review, we focused on low-level laser therapy but 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 limitations to this one. First, the exclusion of articles published in other languages than English could not be ignored. Second, no study had evaluated the effect of LLLT throughout the course of treatment. All studies were interested in a single step whose canine retraction was the movement the most studied. Third, the causal relationship between LLLT and OTM acceleration was not explicated and remains undetermined due to the lack of histological and biological study. Last but not least, this systematic review was not registered in PROSPERO that might be an additional gap (lacune).

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.

Comment [Z1]: When it comes to flexicorticotomy or corticotomy, it has been a questioned procedure, even at an ethical level, there are orthodontic systems that today have the capacity to cause bone expansion, such as self-ligating and self-ligating pits 21, which avoids previous treatments and achieves the desired expansions less weather

ETHICAL APPROVAL

It is not applicable.

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