Review Article

The Protocol of Low-level Laser Therapy in Orthodontic Practice: A Scoping Review of Literature

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Abstract

Low-level laser therapy (LLLT) has been widely investigated as an adjunct technique for orthodontic treatment due to photobiomodulation effect. LLLT appears to be supportive for an orthodontic practice in terms of tooth movement acceleration, pain relief, and root resorption management. The decrease in these adverse effects will enhance the compliance in orthodontic patients, which could positively impact treatment outcomes. However, there seemed to be inconsistency in the impact of LLLT as well as its laser and treatment parameters. This scoping review aimed to evaluate the impact of different irradiation parameters on tooth movement acceleration, pain relief, and root resorption as well as to construct a protocol of LLLT in orthodontic practice. The search was conducted across PubMed, Scopus, Web of Science, Embase, Google Scholar, and the reference lists of identified articles. The last search was conducted on October 10, 2021 to identify experiments in humans regarding the application of LLLT as noninvasive treatment in orthodontic practice published between 2010 and 2021. However, they were excluded if they were not clinical research, if they did not report the source of laser, or if they were not relevant to tooth movement, pain perception, and root resorption, or if they were not available in English or in full-text. Following the systematic search and selection process, 60 articles were included in this review. A majority of included articles were published in the past few years. The findings of this review supported the application of LLLT in orthodontic practice with purposes of tooth movement acceleration and pain reduction. The positive impact of LLLT on root resorption had not been clearly evident yet. As this review demonstrated heterogeneity of both laser and treatment parameters, further research should be required to ensure the effectiveness of its specific parameters in orthodontic practice.

Keywords: *LLLT, low-level laser therapy, orthodontic practice, pain, photobiomodulation, root resorption, scoping review, tooth movement*

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Introduction

Orthodontic care is a treatment procedure where long-term compliance of patients is required. The treatment duration can range from 14 to 33 months, with an average time of 19.9 months.[1] The long treatment time is not only burdensome for patients which could negatively impact the compliance of patients, but also there are a variety of side effects, such as root resorption, alveolar bone resorption, and caries.[2] There is evidence reporting the association between the duration of orthodontic treatment and

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the degree of root resorption.[3,4] Orthodontic pain is another unpleasant side effect, which seems to be one of the concerns among patients. Discomfort, dull pain, and hypersensitivity from orthodontic care are unavoidable,[5] which can lead to incompliance or early termination of treatment.[6] Consequently, research to minimize these adverse effects has currently been a focus of orthodontics, with the purpose of the enhancement in compliance and comfort among patients.

The application of noninvasive low-level laser therapy (LLLT) has been introduced in an orthodontic practice in order to favor the biomechanics of tooth movements. LLLT can be considered as an alternative approach in offering analgesic and anti-inflammatory effects.[7] It can have a positive impact on pain relief, tooth movement, and root resorption.[8-10] With a low energy output, LLLT should not raise the temperature of a targeted tissue to over normal body temperature,[11] to avoid negative thermal effects. There seems to be no significant adverse effect of LLLT, compared to drug usage, corticotomy, and electric simulation.[12] This leads to an increase in a number of studies of LLLT as a noninvasive approach in orthodontic practice with the expectation of promoting better experience in patients.

With a large number of studies in the use LLLT in orthodontic practice, there appears to be inconsistency in the impact of LLLT on pain relief, tooth movement, and root resorption. In addition, the variation of LLLT implementation in orthodontic practice was identified, in terms of irradiation (wavelength and radiant power) and treatment parameters (exposure duration and frequency of the therapy). The consistency of LLLT protocol should also be considered for orthodontic education, where its appropriate parameters could be delivered to residents. Therefore, the aims of this scoping review were to evaluate the clinical outcomes of different irradiation parameters on tooth movement acceleration, pain relief, and root resorption as well as to construct a protocol of LLLT in orthodontic practice.

Materials and Methods

Review design

A scoping review of the literature was selected for this study, in order to identify clinical outcomes of LLLT in orthodontic with the purpose of generating a protocol for its implementation. This method is appropriate in scoping available evidence to clarify characteristics or concepts of the focused topic.[13] The scoping review process includes (1) defining research questions or objectives, (2) identifying relevant articles, (3) selecting articles according to inclusion and exclusion criteria, (4) charting the data extracted from included articles, and (5) summarizing and reporting the synthesized data, and (6) consulting experts or external researchers for additional suggestions or recommendations.[14] The information of the included articles was extracted in the following themes: authors, year of publication, study design, research samples, irradiation parameters, and risk of bias assessment [Tables 1–3].

Search strategy

The systematic search was conducted across four databases, which included PubMed, Scopus, Web of Science, and Embase. Search terms with Boolean combinations were piloted and adjusted repetitively to assure the quality of systematic search. A PICOS strategy was employed to develop search terms,[15] including "Orthodontic patient" for **P**opulation, "Low level laser therapy," "LLLT," "Diode laser irradiation," and "Photobiomodulation" for **I**ntervention, "No intervention or non-LLLT approach" for **C**omparison, "Tooth movement," "Pain," and "Root resorption" for **O**utcomes, and "Experimental studies" for **S**tudy type. However, to extend our search results covering as many as available publications, only search terms for **P**opulation, **I**ntervention, and **O**utcomes were implemented, where "Orthodontic" and "Orthodontics" were used instead of "Orthodontic patient." The last search was conducted on 10 October 2021.

Inclusion and exclusion criteria

All types of experimental studies with humans regarding the application of LLLT as noninvasive treatment in orthodontic practice published between 2010 and 2021 were included in this review. However, the identified articles were excluded if they were not clinical research (conducted using animal testing or *in vitro* methods), if they did not report the source of laser, or if their research outcomes were not relevant to tooth movement, pain perception, and root resorption. They were also excluded if they were not available in English or in full text.

Risk of bias assessment for included articles

The Cochrane Collaboration's tool was implemented to assess a risk of bias of all included articles. This tool was selected, as it could support the judgment in evaluating a risk of bias assessment of included studies whether their risk was "low," "high," or "unclear."[16] The six domains of bias were assessed including (1) selection bias, (2) performance bias, (3) detection bias, (4) attrition bias, (5) reporting bias, and (6) other bias.[16] The outcomes of the bias assessment would show whether or not the included articles provided reliable evidence, reflecting the quality in conducting and reporting their experimental designs.

Table 1: Application of LLLT for "accelerating tooth movement" in orthodontic practice

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Positive impact on tooth movement												
Da Silva Sousa *et al.*, 2011[17]	Parallel-group RCT	10 Male: 4 Female: 6 Average age: 13.1	1. LLLT 2. Control	Measurement on digital casts	GaAlAs	780 nm	20 mW	5 J/cm^2	100	Days 0, 3, and 7 (3 days each month)	10 (Buccal: 5; Lingual: 5)	Unclear
Doshi-Mehta *et al.*, 2012[18]	Split-mouth RCT	20 Male: 8 Female: 12 Age range: 12-23	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	808 nm	0.25 mW	Not reported	10	Days 0, 3, 7, and 14 in the first month, and then every 15 days	Day 1: 2 (Buccal: 1; Lingual: 1) Day 3: 10 (Buccal: 5; Lingual: 5)	Low risk
Genc *et al.*, 2013[19]	Split-mouth RCT	20 Male: 6 Female: 14 Average age: 17.8	1. LLLT 2. Control	Measurement in oral cavity and GCF (Nitric oxide)	GaAlAs	808 nm	20 mW	Not reported	100	Days 0, 3, 7, 14, 21, and 28	10 (Buccal: 5; Lingual: 5)	Unclear
Hasan *et al.*, 2017[22]	Parallel-group RCT	26 Male: 6 Female: 20 Average age: 20.07	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	830 nm	150 mW	2.25 J/cm^2	60	Days 0, 3, 7, and 14 in the first month, and then every 15 days	4 (Buccal: 2; Lingual: 2)	High risk
Kochar *et al.*, 2017[23]	Split-mouth RCT	20 Male: 12 Female: 8 Age range: 16-24	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	810 nm	100 mW	5 J/cm^2	100	Days 0, 3, and 7 (3 days every 21 days)	10 (Buccal: 5; Lingual: 5)	Low risk
Qamruddin *et al.*, 2017[24]	Split-mouth RCT	20 Male: 10 Female: 10 Average age: 19.8	1. LLLT 2. Control	Measurement on 3D dental models	GaAlAs	940 nm	100 mW	7.5 J/cm^2	30	Immediately after the force application	10 (Buccal: 5; Lingual: 5)	High risk
Üretürk *et al.*, 2017[25]	Split-mouth RCT	15 Male: 7 Female: 8 Average age: 16.2	1. LLLT 2. Control	Measurement on dental casts and GCF (IL-1β and TGF-β1)	GaAlAs	820 nm	20 mW	5 J/cm^2	100	Days 0, 3, 7, 14, 21, 33, 37, 60, 63, and 67	10 (Buccal: 5; Lingual: 5)	Unclear

Table 1: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Abdelhameed and Refai, 2018[26]	Split-mouth RCT	30 Age range: 15-25	1. LLLT 2. Control 3. Micro-osteoperforations (MOPs) 4. MOPs and LLLT	Measurement in oral cavity	GaAlAs	810 nm	Not reported	Not reported	Not reported	Days 0, 3, 7, and 14 in the first month, and then every 15 days	Along both buccal and lingual surfaces of the root	Unclear
Arumughan *et al.*, 2018[27]	Split-mouth RCT	12 Age range: 17-35	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	810 nm	100 mW	Not reported	100	Days 0, 21, 42, and 63	10 (Buccal: 5; Lingual: 5)	Unclear
Guram *et al.*, 2018[28]	Split-mouth RCT	20 Male: 8 Female: 12 Average age: 19.75	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	810 nm	200 mW	5 J/cm^2	30	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
Jose *et al.*, 2018[29]	Split-mouth RCT	12	1. LLLT 2. Control	GCF (IL-1β and PGE_2)	GaAlAs	810 nm	100 mW	Not reported	100	Immediately after the force application	10 (Buccal: 5; Lingual: 5)	Unclear
Dakshina *et al.*, 2019[30]	Parallel-group RCT	24 Age range: 18 or above	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	980 nm	2000 mW	15 J/cm^2	30	Every 4 weeks	2 (Buccal: 1; Lingual: 1)	Unclear
Chandran *et al.*, 2020[32]	Experimental design	32 Average age: 19.15	1. LLLT + Conventional bracket 2. LLLT + Self-ligating bracket 3. Control	Measurement on dental casts	GaAlAs	808 nm	Not reported	8 J/cm^2	60	Days 0, 3, 7, and 14 in the first month, and then every 15 days	4 (Buccal: 2; Lingual: 2)	High risk
Jivrajani and Bhad, 2020[33]	Split-mouth RCT	10 Male: 3 Female: 7 Age range: 14-24	1. LLLT 2. Control	Measurement on dental casts and GCF (MMP-9)	GaAlAs	980 nm	30 mW	Not reported	30	Days 0, 3, 7, and 14 in the first month, and then every 15 days	10 (Buccal: 5; Lingual: 5)	Low risk
Kamran, 2020[34]	Split-mouth RCT	44 Male: 17 Female: 27 Average age: 14.8	1. LLLT 2. Control	GCF (OPG, OPN, and RANKL)	Laser Duo, MMOptics	808 nm	100 mW	25 J/cm^2	100	Immediately, 3 days, 1 week, and 2 weeks after the force application, and then every month	10 (Buccal: 5; Lingual: 5)	Unclear

Table 1: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Lalnunpuii *et al.*, 2020[35]	Parallel-group RCT	65 Male: 24 Female: 41 Average age: 17.53	1. LLLT + Conventional bracket 2. LLLT + Self-ligating bracket 3. Control	Measurement on dental casts	GaAlAs	658 nm	8 mW	2.29 J/cm^2	100	Days 0, 3, 7, and 14 in the first month, and then every 15 days	10 (Buccal: 5; Lingual: 5)	High risk
Storniolo-Souza *et al.*, 2020[37]	Split-mouth RCT	11	1. LLLT 2. Control	Measurement on 3D dental models	ArGaA	780 nm	40 mW and 70 mW (maxillary palatal)	10 J/cm^2 and 35 J/cm^2 (maxillary palatal)	150	Every 4 weeks	10 (Buccal: 5; Lingual: 5)	Unclear
Farhadian *et al.*, 2021[38]	Parallel-group RCT	60 Male: 14 Female: 46 Average age: 21.7	1. LLLT 2. LED 3. Control	Measurement on 3D dental models	GaAlAs	810 nm	100 mW	4 J/cm^2	18	Days 0, 3, 30, and 60	6 (Buccal: 3; Lingual: 3)	Low risk
Qamruddin *et al.*, 2021[39]	Split-mouth RCT	20 Male: 10 Female: 10 Average age:20.25	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	940 nm	100 mW	7.5 J/cm^2	30	Every 3 weeks	10 (Buccal: 5; Lingual: 5)	High risk
Türker *et al.*, 2021[40]	Split-mouth RCT	20 Average age:16.35	1. LLLT 2. Piezocision	Measurement on 3D dental models	Epic 10; Biolase	940 nm	400 mW	5 J/cm^2	80	Days 0, 3, 7, 14, 21, and 28	8 (Buccal: 4; Lingual: 4)	Unclear
Zheng and Yang, 2021[41]	Split-mouth RCT	12 Male: 4 Female: 8 (Age: 18-28)	1. LLLT 2. Control	Measurement on 3D dental models and GCF (IL-1β, RANKL, and OPG)	Doctor Smile LAMBDA SpA	810 nm	100 mW	6.29 J/cm^2	160	Days 0, 7, 14, and 21	4 (Buccal: 2; Lingual: 2)	Unclear
No positive impact on tooth movement												
Heravi *et al.*, 2014[20]	Split-mouth RCT	20 Male: 3 Female: 17 Average age: 22.1	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	810nm	200 mW	21.4 J/cm^2	300	Immediately after the force application and on Days 3, 7, 11, and 15	10 (Buccal: 5; Lingual: 5)	High risk

Table 1: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Dalaie *et al.*, 2015[21]	Parallel-group RCT	12 Male: 3 Female: 9 Average age: 20.1	1. LLLT 2. Control	Measurement on dental casts	GaAlAs	880 nm	100 mW	5 J/cm^2	80	Not reported	8 (Buccal: 4; Lingual: 4)	Low risk
Farid *et al.*, 2019[31]	Split-mouth RCT	16 Female: 16 Average age: 21.5	1. LLLT + Corticotomy 2. Corticotomy (control)	Measurement on dental casts	InAlAs	940 nm	Not reported	5 J/cm^2	240	Immediately, 1 week, 2 weeks, 3 weeks after the force application, and then every 2 weeks	2 (Buccal: 1; Lingual: 1)	Unclear
Mistry *et al.*, 2020[36]	Split-mouth RCT	21 Male: 7 Female: 14 Average age: 17.4	1. LLLT 2. Control	Measurement on 3D dental models	GaAlAs	808 nm	200 mW	Not reported	80	Days 0, 28, and 56.	8 (Buccal: 4; Lingual: 4)	Low risk

Results

Literature identified from the search

There were 818 articles identified across the four databases (PubMed, Scopus, Web of Science, and Embase). There were also five additional articles identified from Google Scholar and the reference lists of identified articles. Following the removal of 492 duplicates, 331 titles and abstracts were initially screened against the inclusion and exclusion criteria. One hundred and ninety-nine articles were excluded, as they were not experimental research with humans of LLLT in orthodontic practice. Finally, 134 full-texts were considered, and 74 of them were excluded: 36 articles were not conducted with an experimental design (e.g., case reports or reviews); eleven were animal research; ten did not report the source of laser; six were not the use of noninvasive LLLT in orthodontic practice (with purposes of tooth movement, pain reduction, or root resorption); eight were the use of light-emitting diode (LED); one was not available in full-text; and two were not available in English. Consequently, 60 articles were included in this scoping review. This article selection process was presented in Figure 1.

Characteristics of included articles

The 60 experimental studies included in this review. The tooth movement acceleration was evaluated as the outcomes in 25 articles.[17-41] The pain reduction was assessed in 40 experiments.[18,20,21,23,24,28,37-39,42-72] Only five articles evaluated the impact of LLLT on root resorption.[17,73-76] The included experiments consisted of 24 parallel-group randomized control trials (RCTs), and 34 split-mouth RCTs, whereas two articles did not report how their subjects were allocated into each group. Fifty articles assessed only an aspect of LLLT impact in orthodontic practice (tooth movement, pain perception, or root resorption), whereas 10 studies evaluated multiple outcomes.[17,18,21,23,24,28,37-39,52] According to the year of publication, 31 articles were made available in the past few years (2019–2021), whereas 29 publications were published between 2010 and 2018.

Characteristics of included low-level laser therapy

As expected, there appeared to be various parameters of LLLT used in orthodontic practice, especially when considering the laser parameters. A couple of laser sources were used including GaAlAs, GaAs, InGaAlP, He-Ne, InAlAs, Nd:YAG, and InGaAs. GaAlAs, was used as a laser diode in a majority of experiments, whereas six articles reported just the model and registered trademark without reporting the chemical elements.[34,40,41,54,63,67] The wavelength of laser ranged from 630 to 1064 nm, which 810–980 nm appeared to be the common parameters used

Table 2: Application of LLLT for "relieving pain" in orthodontic practice

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Positive impact on pain relief												
Bicakci *et al.*, 2012[42]	Split-mouth RCT	19 Male: 8 Female: 11 Average age: 13.9	1. LLLT 2. Control	VAS and GCF (PGE_2)	GaAlAs	820 nm	50 mW	7.96 J/cm^2	20	Just before and 24 h after the force application	4 (Buccal: 2; Lingual: 2)	Unclear
Doshi-Mehta *et al.*, 2012[18]	Split-mouth RCT	20 Male: 8 Female: 12 Age range: 12-23	1. LLLT 2. Control	VAS	GaAlAs	800 nm	0.7 mW	Not reported	30	Days 0, 3, 7, and 14 in the first month, and then every 15 days	Day 1: 2 (Buccal: 1; Lingual: 1) Day 3: 10 (Buccal: 5; Lingual: 5)	Low risk
Artés-Ribas *et al.*, 2013[44]	Split-mouth RCT	20 Male: 6 Female: 14 Average age: 26.4	1. LLLT 2. Control	VAS	GaAlAs	830 nm	100 mW	Not reported	120	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
Domínguez *et al.*, 2013[45]	Parallel-group RCT	59 Male: 19 Female: 40 Average age: 24.3	1. LLLT 2. Control	VAS	GaAlAs	830 nm	100 mW	Not reported	44	At the final acrhwire visit	Along both buccal and lingual surfaces of the root	Low risk
Kim *et al.*, 2013[46]	Parallel-group RCT	88 Male: 23 Female: 65 Average age: 22.7	1. LLLT 2. Control	VAS	AlGaInP	635 nm	6 mW	Not reported	120	Every 12 h for a week	4 (Buccal: 2; Lingual: 2)	Low risk
Nóbrega *et al.*, 2013[47]	Parallel-group RCT	60 Male: 22 Female: 38 Average age: 17.5	1. LLLT 2. Control	VAS	GaAlAs	830 nm	Not reported	Not reported	125	Immediately after the force application	Buccal at apex1 and interradicular 3	Low risk
Eslamian *et al.*, 2014[48]	Split-mouth RCT	37 Male: 12 Female: 25 Average age: 24.97	1. LLLT 2. Control	VAS	GaAlAs	810 nm	100 mW	2 J/cm^2	200	Immediately after and 24 h after the force application	10 (Buccal: 5; Lingual: 5)	Low risk

Table 2: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Marini *et al.*, 2015[49]	Parallel-group RCT	120 Male: 64 Female: 56 Average age: 23.01	1. LLLT 2. Placebo 3. Control	VAS	GaAs	910 nm	160 mW	Not reported	340	Immediately after the force application	2 (Buccal: 1; Lingual: 1)	Low risk
Sobouti *et al.*, 2015[50]	Split-mouth RCT	27 Male: 16 Female: 11 Average age: 15.3	1. LLLT 2. Control	VAS	He-Ne	632.8 nm	10 mW	6 J/cm^2	240	Immediately after the force application	Along both buccal and lingual surfaces of the root	Low risk
Almallah *et al.*, 2016[51]	Split-mouth RCT	36 Male: 10 Female: 26 Average age: 18.4	1. LLLT 2. Control	VAS	GaAlAs	830 nm	100 mW	4 J/cm^2	28	Immediately after and 24 h after the force application	16 (Buccal: 8; Lingual: 8)	Low risk
Bayani *et al.*, 2016[52]	Split-mouth RCT	100 Male: 34 Female: 66 Average age: 17.6	1. LLLT 660 nm 2. LLLT 810 nm 3. Ibuprofen 4. bite wafer 5. Placebo medication	VAS	InGaAlP	660 nm	200 mW	14.3 J/cm^2	30	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
					GaAlAs	810 nm	200 mW	3.6 J/cm^2	30	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	
Farias *et al.*, 2016[53]	Split-mouth RCT	28 Male: 13 Female: 15 Average age: 23.85	1. LLLT 2. Control	VAS	GaAlAs	810 nm	100 mW	2 J/cm^2	45	Immediately after the force application	3 (Buccal: 3)	Low risk
Pesevska *et al.*, 2016[54]	Experimental design	30	1. LLLT 2. Control	NRS	Scorpion D-405 7A®	630-670 nm	20 mW	Not reported	60/Q	Immediately after and 4 days after the force application	Not reported	High risk
Qamruddin *et al.*, 2016[55]	Parallel-group RCT	88 Male: 28 Female: 60 Average age: 18.56	1. LLLT 2. Control	NRS	GaAlAs	940 nm	200 mW	4 J/cm^2	60	Immediately after the force application	3 (Buccal: 3)	Low risk

Table 2: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Kochar *et al.*, 2017[23]	Split-mouth RCT	20 Male: 12 Female: 8 Age range: 16-24	1. LLLT 2. Control	VAS	GaAlAs	810 nm	100 mW	5 J/cm^2	100	Days 0, 3, and 7 (3 days every 21 days)	10 (Buccal: 5; Lingual: 5)	Low risk
Qamruddin *et al.*, 2017[24]	Split-mouth RCT	20 Male: 10 Female: 10 Average age: 19.8	1. LLLT 2. Control	NRS	GaAlAs	940 nm	100 mW	7.5 J/cm^2	30	Immediately after the force application	10 (Buccal: 5; Lingual: 5)	Low risk
Guram *et al.*, 2018[28]	Split-mouth RCT	20 Male: 8 Female: 12 Average age: 19.75	1. LLLT 2. Control	Wong-Baker faces pain rating scale	GaAlAs	810 nm	200 mW	5 J/cm^2	30	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
Qamruddin *et al.*, 2018[57]	Split-mouth RCT	42 Male: 16 Female: 26 Average age: 19.81	1. LLLT 2. Control	NRS	GaAlAs	940 nm	100 mW	7.5 J/cm^2	30	Immediately after the force application	10 (Buccal: 5; Lingual: 5)	Low risk
Wu *et al.*, 2018[58]	Parallel-group RCT	40 Male: 10 Female: 30 Average age: 20.8	1. LLLT 2. Control	NRS	GaAlAs	810 nm	400 mW	2 J/cm^2	120	Immediately after, and then 2h, 24h, 4 days and 7 days after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
Celebi *et al.*, 2019[59]	Parallel-group RCT	60 Male: 30 Female: 30 Age range: 11-23	1. LLLT 2. Mechanical vibration 3. Control	VAS	GaAlAs	820 nm	50 mW	1.76 J/cm^2	96	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Unclear
Giudice *et al.*, 2019[60]	Parallel-group RCT	84 Male: 41 Female: 43 Average age: 16.5	1. LLLT 2. Placebo 3. Control	NRS	GaAlAs	980 nm	1000 mW	27 J/cm^2 for molar segment 24 J/cm^2 of anterior segment	150	Immediately after the force application	Not reported	Low risk

Table 2: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Martins *et al.*, 2019[61]	Parallel-group RCT	62 Male: 26 Female: 36 Average age: 19.8	1. LLLT 2. Control	VAS	GaAlAs	830 nm	100 mW	95 J/cm^2	240	Just before and immediately after, 14 h and 28 h after the force application	8 (Buccal: 4; Lingual: 4)	Low risk
Almallah *et al.*, 2020[62]	Split-mouth RCT	36 Male: 12 Female: 24 Average age: 17.44	1. LLLT 2. Control	VAS	GaAlAs	830 nm	100 mW	4 J/cm^2	224	An hour before and an hour after the force application	8 (Buccal: 4; Lingual: 4)	Low risk
Anicic *et al.*, 2020[63]	Split-mouth RCT	22 Male: 10 Female: 12 Average age: 15.1	1. LLLT 2. Control	VAS	Laser HF, Hager-Werken GmbH & Co.	660 nm	90 mW	21.6 J/cm^2	480	Immediately after and 24 h after the force application	6 (Buccal: 3; Lingual: 3)	Low risk
El Shehawy *et al.*, 2020[64]	Parallel-group RCT	26 Male: 10 Female: 16	1. LLLT 2. Control	VAS	GaAlAs	635 nm	20 mW	6.5 J/cm^2	100	Days 0, 3, 7, and 14 in the first month	10 (Buccal: 5; Lingual: 5)	Unclear
Liu *et al.*, 2020[66]	Parallel-group RCT	150 Male: 88 Female: 72 Average age: 21.7	1. LLLT 2. Placebo 3. Control	VAS and GCF (proinflammatory factors and pain related substance)	Nd:YAG	1064 nm	Not reported	Not reported	120	Immediately after the force application and then every day for the first week	6 (Buccal: 3; Lingual: 3)	Low risk
Matys *et al.*, 2020[67]	Parallel-group RCT	76 Male: 21 Female: 55 Average age: 35.1	1. LLLT 2. Ozone 3. Control	NRS	Lasotronix	635 nm	400 mW	1.59 J/cm^2	115	Immediately after the force application	23 (from maxillary right first molar to the maxillary left first molar)	Unclear
Nicotra *et al.*, 2020[68]	Parallel-group RCT	56 Male: 29 Female: 27 Average age: 12.03	1. LLLT 2. Placebo 3. Control	NRS	GaAlAs	980 nm	1000 mW	1 J/cm^2	30	Immediately after the force application	Along both buccal and lingual sides	Low risk
Oza *et al.*, 2020[69]	Parallel-group RCT	120 Male: 47 Female: 73 Average age: 18.04	1. LLLT 2. Topical anesthetic gel 3. TENS 4. Control	VAS	GaAlAs	830 nm	200 mW	Not reported	60	Immediately after the force application	3 (Buccal: 3)	Unclear

Table 2: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Ren *et al.*, 2020[70]	Split-mouth RCT	27 Male: 5 Female: 22 Average age: 47	1. LLLT 2. Control	VAS and GCF (IL-1β, PGE_2, substance P)	GaAlAs	940 nm	800 mW	8.6 J/cm²	60	Immediately, 1 day, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks after the force application, and then every month	Along buccal surface of the root	Low risk
Sfondrini *et al.*, 2020[71]	Parallel-group RCT	26 Male: 9 Female: 17 Average age: 11.8	1. LLLT 2. Control	Wong-Baker faces pain rating scale	GaAlAs	830 nm	150 mW	7.5 J/cm²	20	Immediately after the force application	4 (Buccal: 2; Lingual: 2)	Low risk
Qamruddin *et al.*, 2021[39]	Split-mouth RCT	20 Male: 10 Female: 10 Age range: 12-30	1. LLLT 2. Control	NRS	GaAlAs	940 nm	100 mW	7.5 J/cm²	30	Every 3 weeks	10 (Buccal: 5; Lingual: 5)	Low risk
No positive impact on pain relief												
Abtahi *et al.*, 2013[43]	Split-mouth RCT	29 Male: 24 Female: 5 Average age: 15.03	1. LLLT 2. Control	VAS	GaAs	904 nm	200 mW	Not reported	30	Daily for five days	4 (Buccal: 2; Lingual: 2)	Low risk
Heravi *et al.*, 2014[20]	Split-mouth RCT	20 Male: 3 Female: 17 Average age: 22.1	1. LLLT 2. Control	VAS	GaAlAs	810nm	200 mW	21.4 J/cm²	300	Immediately after the force application and on Days 3, 7, 11, and 15	10 (Buccal: 5; Lingual: 5)	Low risk
Dalaie *et al.*, 2015[21]	Parallel-group RCT	12 Male: 3 Female: 9 Average age: 20.1	1. LLLT 2. Control	Wong-Baker faces pain rating scale	GaAlAs	880 nm	100 mW	5 J/cm²	80	Not reported	8 (Buccal: 4; Lingual: 4)	Low risk
Hasan *et al.*, 2018[56]	Split-mouth RCT	26 Male: 7 Female: 19 Age range: 16-22	1. LLLT 2. Control	VAS	GaAlAs	830 nm	150 mW	2.25 J/cm² 9 J/cm²	30 and 120	Immediately after the force application	2 (Buccal: 2)	Low risk

Table 2: Continued

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Hasan *et al.*, 2020[65]	Parallel-group RCT	26 Male: 6 Female: 20 Average age: 20.07	1. LLLT 2. Control	VAS	CMS Dental ApS	830 nm	150 mW	Not reported	60	Immediately after the force application	4 (Buccal: 2; Lingual: 2)	Low risk
Storniolo-Souza *et al.*, 2020[37]	Split-mouth RCT	11 Average age: 14.04	1. LLLT 2. Control	VAS	ArGaA	780 nm	40 mW and 70 mW (at maxillary palatal)	10 J/cm^2 and 35 J/cm^2 (at maxillary palatal)	150	Every 4 weeks	10 (Buccal: 5; Lingual: 5)	Low risk
Celebi *et al.*, 2021[72]	Parallel-group RCT	63 Male: 30 Female: 33 Age range: 12-24	1. LLLT 2. Chewing gum 3. Control	VAS	GaAlAs	820 nm	50 mW	1.76 J/cm^2	96	Immediately after the force application	6 (Buccal: 3; Lingual: 3)	Unclear
Farhadian *et al.*, 2021[38]	Parallel-group RCT	60 Male: 14 Female: 46 Average age: 21.7	1. LLLT 2. LED 3. Control	VAS	GaAlAs	810 nm	100 mW	4 J/cm^2	18	Days 0, 3, 30, and 60	6 (Buccal: 3; Lingual: 3)	Low risk

Table 3: Application of LLLT for reducing root resorption in orthodontic practice

Author(s) (year)	Type of study	Research samples (patients)	Comparison groups	Assessment	Source of light	Wavelength	Average radiant power	Energy density	Exposure duration (s)	Frequency of LLLT use	Points of irradiation	Risk of bias assessment
Positive impact on root resorption												
Nayyer *et al.*, 2021[76]	Split-mouth RCT	22 Male: 11 Female: 11 Average age: 20	1. LLLT 2. Control	Root surface analysis with a non-contact 3D optical profilometer	InGaAs	980 nm	100 mW	Not reported	100	Days 0, 3, 7, 11, 15, and 28	10 (buccal: 5; lingual: 5)	Unclear
No positive impact on root resorption												
Da Silva Sousa *et al.*, 2011[17]	Parallel-group RCT	10 Male: 4 Female: 6 Average age: 13.1	1. LLLT 2. Control	Measurement on radiograph	GaAlAs	780 nm	20 mW	5 J/cm^2	100	Days 0, 3, and 7 (3 days each month)	10 (buccal: 5; lingual: 5)	Unclear
Khaw *et al.*, 2018[73]	Split-mouth RCT	20 Male: 8 Female: 12 Average age: 15.75	1. LLLT 2. Control	Micro-CT	GaAlAs	660 nm	75 mW	Not reported	120	Every week	8 (buccal: 4; lingual: 4)	Low risk
Ng *et al.*, 2018[74]	Split-mouth RCT	20 Male: 10 Female: 10 Average age: 16.55	1. LLLT 2. Control	Micro-CT	GaAlAs	808 nm	180 mW 360 mW	1.6 J/point	72 (cont.) 36 (pulse)	Days 0, 2, 3, 7, 14, and 21	8 (buccal: 4; lingual: 4)	Low risk
Goymen *et al.*, 2020[75]	Parallel-group RCT	30 Male: 14 Female: 16 Average age: 16.27	1. LLLT 2. LED 3. Control	Micro-CT	GaAlAs	810 nm	Not reported	8 J/cm^2	Not reported	Days 0, 3, 7, 14, 21, and 28	Not reported	Unclear

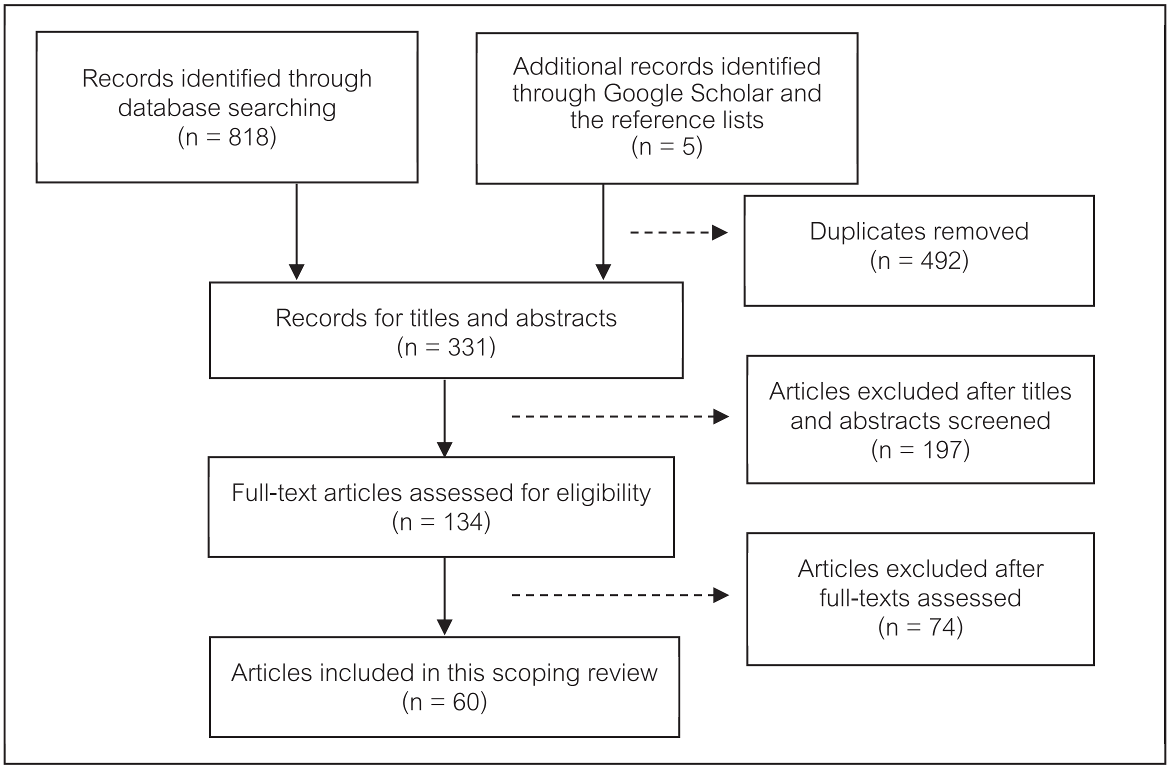

Figure 1: Article's selection process of this scoping review

for LLLT in orthodontic practice. The selection of LLLT operating mode seemed to be consistent, as nearly all of the included articles considered the use of continuous wave, rather than a pulsed mode.

According to the treatment parameters, there were several points to be considered such as exposure duration, frequency of laser therapy, and application techniques (irradiation points). The exposure durations were varied from 10 to 480 s, depending on the area exposed to the irradiation. The frequency of LLLT seemed to be very varied, and most studies employed LLLT immediately after the application of orthodontic force. In case that the multiple sessions were designed, LLLT appeared to be more frequently applied in the initial phase (the first 2 weeks). The irradiation points were mostly applied on both buccal and palatal/lingual surfaces, with the common techniques being 6–8 points for a tooth. A couple of studies applied LLLT by moving a laser tip along the root of a tooth on buccal and/or lingual surfaces, rather than as a point.

The Application of Low-Level Laser Therapy for "Accelerating Tooth Movement" in Orthodontic Practice

Overview of low-level laser therapy research on tooth movement

The outcome of LLLT on tooth movement acceleration was evaluated in 25 articles [Table 1]. The acceleration of tooth movement could be evaluated by measuring the moving distance during the canine retraction or the duration of complete treatment for decrowding. The tooth movement could be measured in an oral cavity,[19,26] on dental casts[17,18,20-23,25,27,28,30-33,35,39] or digital models[24,36-38,40,41] by using a digital caliper or stereomicroscope with appropriate reference points. Irregularity index representing horizontal overlapping or crowding can also be used for the evaluation.[22] Six experiments additionally collected gingival crevicular fluid (GCF) to analyze tooth movement-related substance, including IL-1β, TGF-β1, PGE_2, MMP-9, OPG, OPN, and RANKL.[19,25,29,33,34,41]

The impact of low-level laser therapy on tooth movement acceleration

LLLT was found to be effective in accelerating tooth movement, as positive outcomes were shown in 21 from 25 articles [Table 1]. According to the four studies reporting no positive outcomes,[20,21,31,36] one experiment evaluated the effect of LLLT as supplementary to corticotomy.[31] This might result in no significant difference between LLLT and non-LLLT groups, as corticotomy had already accelerated the tooth movement.

The parameters of low-level laser therapy for a purpose of tooth movement acceleration

GaAlAs appeared to be the most common laser diode used for accelerating tooth movement, which was used in 20 from 25 articles [Table 1]. Other laser diodes included ArGaA and InAlAs. The wavelength was ranging from 658 nm to 980 nm, with the most common protocol seemed to be 810 nm. The average radiant power was very varied, ranging from 0.25 to 2000 mW, which was likely to depend on the size of laser tip.

In terms of clinical application, a majority of research applied LLLT immediately after the force application followed by Days 3, 7, and 14 for the first month and then every 15 days. The irradiation points for each tooth were varied from two to ten, which the 10-point protocol appeared to be the most common. All experiments applied LLLT on both buccal and lingual surfaces; however, one of them moved the laser tip along the root area, rather than a points technique.[26] The exposure time was varied from 10 to 300 s, leading to the variation of irradiation target from 2.25 to 25 J/cm^2.

The application of low-level laser therapy for "relieving pain" in orthodontic practice

Overview of low-level laser therapy research on pain relief

Pain relief seemed to be the most common outcome of LLLT research. There were 40 experimental studies reporting the outcomes of LLLT on pain relief [Table 2]. The level of pain was typically measured at leveling and canine retraction phases as well as at the period of separator placement. A couple of methods were designed to assess level of pain in orthodontic patients. Visual analog scales (VASs) appeared to be the most popular tool to gather self-perceived pain, which was used in 29 articles.[18,20,23,37,38,42-53,56,58,59,61-66,69,70,72] Eight articles employed numerical rating scales (NRS).[24,39,54,55,57,60,67,68] The Wong–Baker faces pain rating scale, used in three articles, could also be applied to collect self-reported pain.[21,28,71] Three studies GCF to measure pain-related substance, including prostaglandin E_2 (PGE_2), substance P, and pro-inflammatory factors.[42,66,70]

The impact of low-level laser therapy on pain relief

LLLT appeared to have a positive impact on the reduction of orthodontic treatment-related pain. There were 32 experimental researches reporting the positive impact of LLLT on pain relief, compared with conventional or other techniques [Table 2]. There was an experiment comparing the impact of LLLT on pain reduction with anesthetic gel and transcutaneous electrical nerve stimulation, which the laser method appeared to be more effective.[69] Only eight articles reported no positive impact of LLLT on pain reduction.

The parameters of low-level laser therapy for a purpose of pain relief

When considering the laser parameters, GaAlAs was the most popular laser diode for pain relief, as reported in 30 from 40 articles [Table 2]. Other laser diode included He-Ne, GaAs, InGaAlP, Nd:YAG, and ArGaA. The wavelength was ranging from 630 to 1064 nm, where 830 nm seemed to be the most common wavelength (reported in ten experiments) followed by 810 (eight articles) and 940 nm (five articles). The average radiant power was very varied, ranging from 0.7 to 800 mW.

Similar to the clinical application for tooth movement acceleration, nearly all experiments applied LLLT immediately after the force application. In case more than a session of LLLT was applied, the application tended to be more frequent during the first week (Days 0, 3, and 7). There were also three articles reporting the LLLT use before the force application.[42,61,62] The irradiation points for each tooth were varied from 2 to 16, which 6 and 10 points appeared to be the common instruction. They were typically applied on both buccal and palatal (lingual) sides. Four experiments reported the use of different technique, where the laser tip was moved along the root of tooth (both buccal and lingual surfaces), showing the positive outcome on pain relief.[45,50,68,70] The exposure time was varied from 20 to 480 s, leading to the variation of energy density from 1 to 35.4 J/cm^2.

The application of low-level laser therapy for "reducing root resorption" in orthodontic practice

Overview of low-level laser therapy research on root resorption

The impact of LLLT on root resorption seemed to be a new research topic, which four from five studies were published over the past few years [Table 3]. A study conducted in 2021 evaluated this impact by measuring the root on the periapical radiograph from the gingival edge of the orthodontic bracket to the root apex at different periods.[17] Following the advanced technology, three articles published between 2018–2020 evaluated the root resorption using microcomputed tomography (micro-CT)[73-75] An experiment published in 2021 enhanced the accuracy of root resorption analysis by using a non-contact three-dimensional optical profilometer.[76]

The impact of low-level laser therapy on a reduction of root resorption

The positive impact of LLLT on root resorption had not been clearly evident. Although four experiments found no positive outcome on root resorption,[17,73-75] one study supported the use of LLLT based on the analysis with the optical profilometer.[76]

The parameters of low-level laser therapy for a purpose of a reduction of root resorption

AlGaAs and InGaAs appeared to be a laser diode used for decreasing induced inflammatory root resorption, with wavelength ranging from 660 nm to 980 nm [Table 3]. The research applying AlGaAs found no positive outcome on a reduction of root resorption. The average radiant power was ranging from 20 to 360 mW, which 100-mw irradiation could be sufficient to offer a positive impact on root reduction.

The clinical application of LLLT for root resorption seemed to be less varied than the other two outcomes. The exposure duration of low-level laser at each point ranged from 72 to 120 s for continuous wave, and one study applied pulsed wave for 36 s.[74] All studies conducted LLLT for a period with the purpose of root resorption, with approximately three to six sessions per month. Similar to the use of LLT for other purposes, LLLT was applied more frequently in the first week. The energy density was ranging from 5 to 8 J/cm^2. Based on the included studies, eight to ten irradiation points were applied for each tooth, divided equally for both buccal and lingual sides.

Discussion

There seems to be an increasing use of LLLT in orthodontic practice, as implied from the trend of research in this topic. There were 48 articles published between 2018 and 2021, compared to 33 publications over the 8-year period (2010–2017). More than ten articles were published in a year from 2018 to 2020. The emphasis of LLLT research has also moved to tooth movement acceleration, in which 18 of 22 articles in this topic were made available in the past 5 years. According to the impact of LLLT on root resorption, four of five articles were published since 2018.

LLLT appeared to have positive outcomes in orthodontic practice. There seemed to be a significant impact on pain relief, tooth movement, and root resorption, as evident by the results retrieved from the included articles. These findings were consistent with previous literature, which LLLT was likely to have a positive effect on healing, nerve regeneration, inflammatory process, pain reduction, proliferation of osteoblasts, bone remodeling, root resorption, and tooth movement.[77-80] Therefore, LLLT can be considered as significantly supportive for an orthodontic practice.

The reduction of orthodontic pain could be considered as one of the significant outcomes of LLLT. Pain could be considered as an important concern in orthodontic practice, as it may discourage patients from the treatment.[6,7] In addition, orthodontic pain appears to be unavoidable, as it is induced from tooth movement during the treatment. Although analgesics appear to be an effective method for pain control, pharmacological actions and adverse effects should be concerned.[81] LLLT could be considered as an alternative option for the non-pharmacological management of pain. These reasons might lead to a popularity of research in the impact of LLLT on the orthodontic pain.

The duration of orthodontic management can be another factor to discourage patients from the treatment. Not only there can be a reduction of patient compliance throughout the long treatment duration, but also the risk of root resorption, alveolar bone resorption, dental caries, and gingivitis seems to be increasing.[2] Tooth movement acceleration, therefore, has become an important topic in orthodontic practice. A great number of studies emphasized on tooth movement acceleration as well as how to measure it.[82,83] Several techniques have been used to accelerate tooth movement, such as biological approaches (e.g., cytokines, prostaglandin, or parathyroid hormone injection), device-assisted techniques, surgical methods (e.g., corticotomy, interseptal alveolar surgery, osteotomy), and LLLT.[82] Although surgical techniques have been proved to enhance tooth movement acceleration,[84] it could be considered more aggressive than other methods. Consequently, LLLT appeared to be one of the most preferable noninvasive approaches for tooth movement acceleration without systemic adverse effects.

External apical root resorption is another major concern in orthodontic practice. It was likely to be one of the most common adverse effects of orthodontic treatment.[85,86] There is evidence reporting a correlation between root resorption and the duration of orthodontic treatment.[87,88] As orthodontically induced inflammatory root resorption seems to be an unavoidable complication,[89] a number of studies aimed to explore its influential factors.[90] One of the expectations is to prevent this adverse effect. However, the evidence of LLLT on the reduction of root resorption was not clear, as only the latest research showed the positive outcome.

This scoping review showed the heterogeneity in both laser and treatment parameters, for example, laser diodes, wavelength, average radiant power, energy density, exposure duration, frequency of LLLT applications, and points of irradiation. Although a number of studies showed no positive outcomes of LLLT in orthodontic practice, there was no clear evidence to suggest whether there were any inappropriate laser parameters for the use in orthodontic practice, as the LLLT parameters of no positive outcomes were found to effective in other research.

The findings retrieved from most of the included studies showed a positive impact of LLLT in orthodontic practice, at least for tooth movement acceleration and pain reduction, with non-significant adverse effects; however, there are limitations and restriction for its implementation. With the laser safety concern, protective equipment such as laser-protection eyeglasses is required for both patients and operators. Another concern of LLLT is its sensitive technique, requiring professional use to obtain the optimal dose of laser. There could be no positive biological impact if too low dose is used; however, too high dose may lead to a bio-suppressive effect.[91] Orthodontic patients, therefore, are required to receive LLLT at a dental office which could be inconvenient for them. In addition, the cost of laser device is quite high, although it is currently less expensive than the past.[72] LED can be considered as alternative photobiomodulation therapy with similar purposes to LLLT,[92,93] as LED device can be used at home without laser safety considerations.[94] Therefore, the impact of LED, especially with a comparison with LLLT, in orthodontic practice should be required to confirm their effectiveness.

There were a few limitations in conducting this scoping review. The data extracted for the analysis included both laser and treatment parameters; however, there were a number of the LLLT parameters that could not be identified in a number of articles. In addition, there were some difficulties in comparing these studies due to parameter variability. As discussed, there were a couple of articles reporting no positive outcomes although their laser and treatment parameters were also similarly used in other studies which supported LLLT in orthodontic practice. Furthermore, the details of research design in a number of articles were not clearly confidently defined, and they were evaluated as "high" or "unclear" risk of bias. Most of the experiments with high risk of bias had a limitation in blinding operators or assessors, so only the patient side was blinded. One of the strengths of this scoping review was the inclusion of all available experimental evidence whether it was evaluated as high, low, or unclear risk of bias, offering the promising opportunities in developing a robust and rigorous systematic review or meta-analysis. Although this review provides available options for the effective use in orthodontic practice, further clinical research with robust design should be required to assure the positive impact of LLLT on the specific parameters in orthodontic practice.

Conclusion

This scoping review supports the use of LLLT in orthodontic practice, as the available evidence tended to reveal its positive impacts on tooth movement acceleration and pain relief. However, there were a number of studies reporting no positive impact of LLLT. In addition, the impact of LLLT on a reduction of root resorption had not been yet clearly evident. As there were little inconsistency of orthodontic impact as well as heterogeneity of both laser and treatment parameters, further research should be required to ensure the effectiveness of its specific parameters in orthodontic practice.

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Conflicts of interest

The authors declare no conflict of interest.

Authors' contribution

Conceptualization: RC, NNS, and KS; methodology: RC, NNS, and KS; investigation: RC and KS; data analysis: RC and KS; validation: RC, NNS, and KS; manuscript writing: RC and KS; manuscript review: RC, NNS and KS. All authors have read and agreed to the published version of the manuscript.

Ethical policy and institutional review board statement

Not applicable.

Patient declaration of consent

Not applicable.

Data availability statement

The data summarized in Tables 1–3 of this review were analyzed from 60 articles listed in the reference section.[17-76]

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