Review Article

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Journal of Orthodontics & Endodontics
ISSN 2469-2980

2018
Vol.4 No.4:14

DOI: 10.21767/2469-2980.100064

Effects of Low Level Laser Therapy on Orthodontic Tooth Movement: A Systematic Review

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Citation: Wilson TM, Jain S (2018) Effects of Low Level Laser Therapy on Orthodontic Tooth Movement: A Systematic Review. J Orthod Endod Vol.4 No.4:14

Abstract

The objective of this systematic review is to extract and study evidences available toassess the effectiveness of low level laser therapy (LLLT) on acceleration of Orthodontic tooth movement. The data sources used were electronic data bases including EMBASE, PubMed, Scopus and Google Scholar. References from collectedarticles were hand searched. Search was not bound with any time limits. Randomized control and clinical trials were also included. Search terms included were orthodontic movement speed/accelerated tooth movement/ LLLT/ Cold-soft diode laser/ Ga-Al-As laser/ low intensity laser/ light therapy/ phototherapy/ photobiostimulation. Only those studies which falls in the moderate to high category on assessment with Cericato et al. method for bias assessment were included. Double extractors did the data collection and at the time of controversies a blinded expert were approached for final decision. Nine studies seemed to be eligible for this study. An energy input of 4.2-8J sq.cm, wavelength of 780-904 nm applied for 80-100 sec/tooth within a time period of 4-6 days per month was found to be effective in demonstrating accelerated orthodontic tooth movement. Some scientific evidence for low level laser therapy causing accelerated orthodontic tooth movement was demonstrated. Those high evidence studies which came up with laser having no benefits on tooth movement explained their pit falls in the discussion, giving reason why they failed to observe any benefit in tooth movement.

Keywords: RCT; LLLT; Accelerated orthodontic tooth movement; Laser; Biostimutlation; Minimal invasive accelerated tooth movement

Received: November 06, 2018; **Accepted:** December 10, 2018; **Published:** December 17, 2018

Introduction

Orthodontia is not that well known for treatment duration as treatment time lasts for one year and a half when fixed appliances are used to treat moderate to severe cases of malocclusion [1]. But the efforts taken for developing and incorporating interventions into treatment for reducing treatment duration is a new ray of hope. Reduced treatment time is adventitious not only for patient's aesthetic and comfort concerns but also avoids the chances for root resorption, periodontal and gingival issues, alveolar bone resorption and caries susceptibility due to longer treatment period [2]. Even though hard tissue alveolar bone and periodontal ligament are in dynamic state of remodeling by combined action of fibroblasts, osteoclasts and osteoblasts, the patients are unaware about this complex condition and ask for faster treatment and this tendency is increasing [3,4]. Literature history have a variety of interventions including surgically assisted corticotomy [5], periodontal ligament distraction, dentoalveolar distractions, piezocision [6], surgically stimulated platelet rich plasma injection [7], bio mechanical self-ligating brackets [8], mechanically stimulating direct electric current, enzymatic micro battery, endogenous piezo electricity, LLLT, pulsed electromagnetic field, pharmacological approaches like injection of prostaglandin, 1,25 di hydroxyl cholecalciferol, corticosteroid hormones, parathyroid hormone, thyroxin [7] and relaxin injections [9] and as latest, nanotechnology with application of dry lubricants, polysulfone brackets, nanobio cells and LIPUS(low intensity pulsed ultra sound) [10]. Current evidences points to the effects of LLLT in orthodontic field as reduced post adjustment pain, increased bone formation at mid palatal sutural

area following rapid palatal expansion and increase in the mini implant stability [11]. LLLT is able to change RANK (Receptor activator of nuclear factor kappa-B)/RANKL(Receptor activator of nuclear factor kappa-B ligand)/OPG (Osteoprotegrin) enzymatic system. Application of LLL causes an increase in the level of RANKL and RANKL/OPG ratio leading to increased bone turn over and there by accelerated tooth movement [11]. Considering the clinical practicability and patient acceptance LLLT had become prime choice of interest. The accelerating effect along with elevated bone remodelling, collagen synthesis, nitrate and nitrite turn over makes LLLT an important one among the minimally invasive procedures for acceleration of tooth movement [12]. For providing a precise view for readers on controversial relation between laser therapy and orthodontic tooth movement this systematic review was conducted with randomised control and clinical trials which experimented on the effect of low level laser treatment on orthodontic tooth movement.

Materials and Methodology

Protocol

This systematic review was conducted following guidelines of PRISMA [13] and guideline for systematic reviews [14].

Objective and guiding question

Objective was to assess the effect of LLLT on orthodontic tooth movement in comparison with control group. Based on PICOS (patient, intervention, comparison, outcome, study design) strategy [13] a guiding questions was formulated.

Patient - who requires orthodontic treatment?

Intervention - Orthodontic tooth movement with adjunctive LLLT

Comparison - Similar group /quadrant with same intervention but lacks LLLT

Outcome - LLLT has an effect on tooth movement

Study design – RCT(randomized control trial) or CCT (case control trial)with blinding

Guiding question formulated was, what is the effect of low level laser therapy in accelerated orthodontic tooth movement when compared with controls.

Inclusion criteria

1. RCT's and CCT's which evaluated or reported the results or treatment parameters associated with accelerated orthodontic tooth movement with LLLT.
2. Orthodontic treatment by canine retraction for space closure.
3. Studies with subjects assigned either as control/placebo and experimental groups.
4. The outcome results should clearly mention whether success achieved or not. It can be either measurable variable of distance moved by tooth or speed of movement or rate of tooth movement or p value or a statement of result.

Exclusion criteria

1. Non randomized trials
2. Animal studies
3. Sample size less than 10
4. Articles, reviews, case reports, opinions, columns in publications,, letters, abstracts and pilot study
5. Publication language other than English.
6. Any studies which used other interventions along with LLLT (E.g. LLLT after corticision)

Information source and search strategy

Based on PRISMA guidelines an electronic search was conducted on four major databases Google scholar, Pub Med, EMBASE and Scopus. Combination of different key words was used for finding relevant studies. Last search was done on 12 JUNE 2018. References of major reviews were used for manual search in order to avoid missing out of any relevant studies while electronic searching. The key words used were orthodontic movement speed/accelerated tooth movement/ LLLT/ cold-soft diode laser/ Ga-Al-As laser/ low intensity laser/light therapy/phototherapy/ photo bio stimulation.

Literature flow

The literature search done is given as **Figure 1**. Out of four electronic databases, a total of 342 articles were evaluated. From

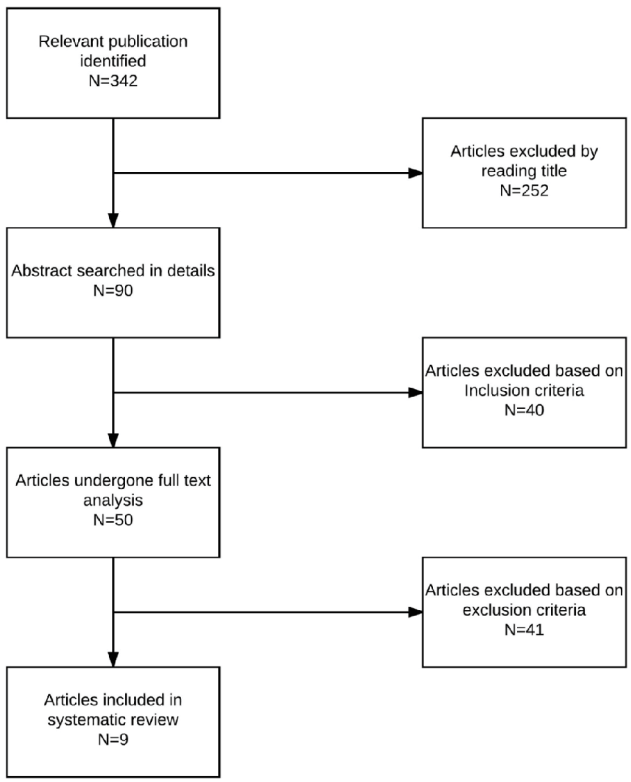

Figure 1 Literature flow.

which 50 full text articles were examined in detail. In final nine studies were taken for final reviewing and quality and quantity data extraction.

After selection, full text articles were downloaded and hard copies were made. A systematic data extraction regarding basic details about articles [3,4,15-21], their sampling details **(Table 1)**, laser and its characteristics **(Table 2)** and clinical findings and outcome **(Table 3)** and statistical outcomes of study **(Table 4)** were done.

Finalized articles were thoroughly evaluated for their quality and potential risk for bias based on an evaluation adapted from Cericato et al. **(Table 5)** [22]. The questions used for evaluation are; Q1. The abstract clearly presents the study objective, methodology, results and conclusion, Q2. The study exposes objective clear and precisely. Q3. The ethical aspects of the research are cited in the text. Q4. The research design is described. Q5. The sample size calculation is reported. Q6. The eligibility (1 point) and exclusion (1 point) criteria are described. Q7. Control groups are used. Q8. The research design is adequate (randomization and blinding). Q9. The statistical tests are described. Q10. The p values are cited. Q11. The study exposes the results clear and precisely. Q12. The study limitations are discussed.

Based on this evaluation each article were classified as low quality (0-8 points), moderate quality (9-11 points) or high quality (12-15 points). Six studies were of high quality and 3 were of medium quality based on risk bias.

Evaluation was done based on criteria for assessing study quality from the center of Reviews and Disseminations in York, UK **(Table 6)** [23].

Strong evidence: Randomized controlled trial, prospective studies/ large study samples

Well-defined and adequate control group clearly defined and clinically relevant variables

Low dropout rate

Relevant statistical analysis

Table 1 Study details.

Author and year	Sample size, gender	Age(years)	Study design and blinding	Malocclusion	Starting time of tooth movement	Anchorage	Follow up period	Force used	Method of measuring
Curz [3]	11 Gender not mentioned	Dec-18	RCT Split mouth Not specified	Lack of space, bimaxillary protrusion	Not mentioned	Nance arch, TPA	2 months	150 gm/month	Digital electronic calliper (in loco)
Limpanichkul [4]	12 4-Male 8-Female	20.11+/-3.4	RCT Split mouth Double blind	Not mentioned	3 months after extraction	Vertical loop stops mesial molar tube	3 months	150 gm/month	Stereo microscope
Youssef [15]	15 Gender not mentioned	14-23	Prospective CCT Split mouth Not mentioned	Lack of space, bimaxillary protrusion	14 days after extraction	Not mentioned	9 weeks	150 gm/21 day	Digital electronic calliper (in cast)
Sousa [16]	10 6-Male 4-Female	13.`1	RCT Split mouth Not mentioned	Lack of space, bimaxillary protrusion	3 months after extraction	Not mentioned	4 months	150 gm/month	Geometric studio 5 software
Doshi Mehta [17]	20 8-Male 12-Female	Dec-23	RCT Split mouth Single blind	Not mentioned	21 days after SS wire placement	TPA	4-5 months	150 gm	Digital electronic calliper (in cast)
Kansal [18]	10 Gender not mentioned	Not mentioned	Prospective CCT Split mouth Triple blind	Lack of space, protrusion	Not mentioned	TPA	63 days	150 gm activation/35th day	Digital electronic calliper (in loco)
Heravi [19]	20 3 -Male 17-Female	22.1+/-5.3	RCT Split mouth Single blind	Not mentioned	3 months after appliance placement	Vertical loop stops mesial to molar tube	56 days	150 gm activation/28th day	Smile analyser software
Dalaie [20]	12 3-Male 17-Female	20.1	Randomised CCT Split mouth Double blind	Not mentioned	3 months after premolar extraction	Not mentioned	67 days	150 gm activation/ month	Digital electronic caliper (in cast)
Ureturk [21]	15 7-Male 8-Female	16.2+/-1.32	RCT Split mouth Not mentioned	Angles class II malocclusion	2 weeks after extraction	Mini implant	90 days	150 gm activation done on 21,42,63,84 days	Ortho analyser soft ware

Table 2 Details of laser used.

Author and year	Type of laser	Wave length	Energy density	Power output	Time/tooth	Points irradiated	Accelerated tooth movement
Curz [3]	Ga-Al-As diode laser	780 nm	5J/sq.cm	20mW	100s	10	Yes
Limpanichkul [4]	Ga-Al-As diode laser	860 nm	25J/sq.cm	100mW	184s	8	No
Youssef [15]	Ga-Al-As diode laser	809 nm	8J/sq.cm	100mW	80s	6	Yes
Sousa [16]	Ga-Al-As diode laser	780 nm	5J/sq.cm	20mW	100s	10	Yes
Doshi Mehta [17]	Ga-Al-As diode laser	810 nm	8J/sq.cm	100mW	100s	10	yes
Kansal [18]	Ga-As diode laser	904 nm	4.2J/sq.cm	12mW	100s	10	Yes
Heravi [19]	Ga-Al-As diode laser	810 nm	21.4J/sq.cm	200mW	300s	10	No
Dalaie [20]	Ga-Al-As diode laser	800 nm	5J/sq.cm	100mW	80s	8	No
Ureturk [21]	Ga-Al-As diode laser	820 nm	5J/sq.cm	20mW	100s	10	Yes

Table 3 Frequency of laser application and rate of tooth movement.

Author and year	Frequency of application (days)	Orthodontic tooth movement rate (in mm)							
		1st month		2nd month		3rd month		4-5th month	
		control	experiment	control	Experiment	control	experiment	control	Experiment
Curz [3]	0,3,7,14,30,33,37,44			33.30+/-0.24	4.39+/-0.27				
Limpanichkul [4]	1,2,3 day of every activation	0.38	0.32	0.74	0.73	1.24	1.29		
Youssef [15]	0,3,7,14 day of every activation	Mean for 9 weeks							
		1.019	2.027						
Sousa [16]	0,3,7 day of activation	0.42+/-0.29	1.16+/-0.51	0.80+/-0.49	2.05+/-0.93	1.60 +/-0.63	3.09+/-1.06		
Doshi Mehta [17]	0,3,7,14,45,75,105,135								
	Maxilla					0.66+/-0.55	1.43 +/-0.15	0.84+/-0.21	1.17+/-0.22
	Mandible					0.35+/-0.28	1.51+/-0.18	0.75+/-0.09	1.11+/-0.17
Kansal [18]	0,3,7,14,21,28,35,42,49,56	1.76+/-1.58	1.68+/-1.20	3.30+/-2.36	3.53+/-2.30				
Heravi [19]	3,7,11,15	Mean for 56 days							
		2.11+/-1.14	2.13+/-1.16						
Dalaie [20]	Single exposure								
	Maxilla	2.49+/-0.98	2.61+/-1.59	4.5+/-0.23	4.98+/-0.78				
	Mandible	2.03+/-1.56	2,29+/-1.36	4.01+/-1.44	3.73+/- 1.08				
Ureturk [21]	0,3,7,14,21,30,33,37,60,63, 67,74,81,84,90 days	Movement for 3 months							
		2.77+/-1.49		3.9+/-1.41					

Table 4 Clinical and statistical out comes and evidence grading.

Author and year	Clinical outcome	Pvalue	Statistical significance	Evidence grading
Curz [3]	34% more movement on experimental side	<0.001	Highly significant	A
Limpanichkul [4]	No difference between both sides	0.77	Non-significant	A
Youssef [15]	1.98 fold more in laser group	<0.05	Significant	B
Sousa [16]	Greater movement on laser side	0.0001 to 0.029	Highly significant	A
Doshi Mehta [17]	30% more on laser side	0.000 to 0.0381	Highly significant	A
Kansal [18]	Faster in laser side	0.34 to 0.69	Non-significant	A
Heravi [19]	No difference between both sides	>0.05	Non-significant	B
Dalaie [20]	No difference between both sides	0.45	Non-significant	B
Ureturk [21]	40% faster on laser side	0.001	Highly significant	A

Moderately strong evidence: Prospective study, cohort, controlled clinical trial, or well-defined retrospective study with large study group

Clearly defined and clinically relevant variables

Low dropout rate

Relevant statistical analysis

Limited evidence: Cross-sectional study

Clinically inadequate result variables

High dropout rate

No control group of its own in the study Limited/no statistical analysis

Addressing the issue in question only in part.

Results

Out of the nine studies which were evaluated for evidence, six

Table 5 Potential risk for bias (Cericato et al).

Author and year	Q.1 (1 point)	Q.2 (1 point)	Q.3 (1 point)	Q.4 (1 point)	Q.5(2 points)	Q.6 (2 points)	Q.7 (1 point)	Q.8 (2 points)	Q.9 (1 point)	Q.10 (1 point)	Q.11 (1 point)	Q.12 (1 point)	Overall score	Quality
Curz [3]	1	1	1	1	0	1	1	0	1	1	1	0	9	Moderate
Limpanichkul [4]	1	1	0	1	0	1	1	2	1	1	1	1	11	Moderate
Youssef [15]	1	1	1	1	0	2	1	1	1	1	1	1	12	high
Sousa [16]	1	1	1	1	0	1	1	2	1	1	1	1	12	High
Doshi Mehta [17]	1	1	1	1	2	1	1	2	1	1	1	0	13	High
Kansal [18]	1	1	1	1	0	1	1	2	1	1	1	1	12	High
Heravi [19]	1	1	1	1	0	1	1	1	1	1	1	1	11	Moderate
Dalaie [20]	1	1	1	1	0	2	1	2	1	1	1	1	13	High
Ureturk [21]	1	1	1	1	0	1	1	2	1	1	1	1	12	High

Table 6 Evaluation for conclusion.

Grade of evidence	Criteria
Grade 1 evidence	Two studies with strong evidence
Grade 2 evidence	One study with strong evidence and two studies with moderate evidence
Grade 3 evidence	Two studies with moderate evidence
Grade 4 evidence	Insufficient scientific support

Table 7 Possible reasons for negative results.

Article	Possible reasons for negative results
Limpanichkul [3]	High energy density used
Kansal [18]	Ga-Ar diode laser used
Heravi [19]	High power output used
Dalaie [20]	Reduced frequency of exposure

were of high evidence and three were of moderate evidence. Out of the six high evidence studies four showed statistically highly significant result and two showed non-significant result. Out of the three medium evidence studies two showed statistically non-significant result and one showed significant result. So in effect there is some evidence for LLLT causing accelerated orthodontic tooth movement. The results of evaluation are given in **Table 4**.

Discussion

From result it is evident that four of high evidence studies and one of moderate evidence study favours accelerated orthodontic tooth movement. On the other hand two of high evidence and two of moderate evidence studies showed non-significant results.

All the four studies which showed non-significant results had a mildly faster tooth movement on experimental side during some period of study.

Studies which failed to demonstrate clinical acceleration in tooth movement had clearly mentioned some factors that might have caused an alteration from the generalized trend of positively accelerated tooth movement **Table 7**.

Conclusion of effect of LLLT on accelerated orthodontic tooth movement was drawn based on the criteria for assessing study quality from the centre of Reviews and Disseminations in York, UK [23] . Comparing the parameters of laser used in different studies, all studies except one study [18] used Ga-Al-As laser in continuous wave mode and all of them fall at a wavelength of 780-904 nm which are infra-red in nature which have low absorption coefficient with haemoglobin and water so high penetration depth in irradiated area [16] .

From **Table 2**, on considering the energy density, 4.2-8 J/sq.cm produced a favourable effect, were as a high value of 25 J/sq.cm and 2.14 J/sq.cm couldn't accelerate tooth movement. It was also observed that based on power output, 20-100 mW gave a positive result whereas 200 mW gave no effect on tooth movement which points that very high power output could be the reason of negative outcome. According to Yamagashi [24] approximately 50% of laser penetrates to a depth of 1 mm in human cortical bone at a power of 60 mW. This explains why the studies used the range of 20-100 mW of power with tissue contact in order to minimise reflection of laser giving positive result.

As far as number of irradiation points are concerned all of studies used 6-10 irradiation points based on root morphology, which points that every study needed distribution of total exposure rather than energy concentrating on certain areas. Irradiation intervals also varied in different studies. Studies with positive result had a range of 4-6 exposures per month whereas study with one exposure and three exposures failed to give positive result **(Table 3)**.

Rate of tooth movement was found to be maximum during 3-4 months of irradiation [16,17] even 30% faster movement was noted [17] .

Another thing to be considered is the systemic effect of phototherapy, if proper shielding is not used in split mouth

studies chances for irradiation of control sites can give faulty readings. No studies mentioned this. Even if the laser effect is controversial in some studies, it is clear that these controversies might be the result of differences in study design, laser variables applied and sample size. Random variables and numerous factors interacting with tooth movement clinically also plays a role in it. Still it remains a question which combination of laser parameters and exposure yields in productive accelerated tooth movement. Hence more studies with adequate sample size are required to set a standard protocol. Excluding the study used laser other than Ga-Al-As, we find a strong evidence of accelerated tooth movement **(Table 2)**.

The bone density varies between maxilla and mandible also between different regions of jaw, so tooth movement at other regions might be a little different from canine even if same dosimetry and laser parameters considered. Hence studies with canine movement were only included in our inclusion criteria. There was a trend of increased maxillary and decreased mandibular tooth movement towards third and fourth month of laser exposure, which may be due to variations in bone density and vasculature.

Some systematic reviews and meta-analysis [25,26] concluded that there is no evidence for LLLT having effect on accelerated orthodontic tooth movement. But they considered small number of studies only. Hence this review tried the best to include latest studies and re-evaluate the effect of LLLT. Incomparable heterogeneity in extracted data was the biggest problem we faced. Lack of large sampled studies with long term evaluation is the drawback of this review.

Conclusion

There is some evidence of accelerated orthodontic tooth movement with low level laser therapy. It is a promissory procedure with a potential to accelerate tooth movement. More high evidence studies are required for concrete conclusion.

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