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ORIGINAL ARTICLE

Effect of low-level laser therapy on orthodontic tooth movement acceleration- systematic review & meta-analysis

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ABSTRACT:
Aim: The aim of this systematic review and meta-analysis was to assess the effects of low-level laser therapy (LLLT) on the orthodontic tooth movement acceleration. **Methodology:** An unrestricted electronic database search in PubMed, Science Direct, Embase, Scopus, Web of Science, Cochrane Library, LILACS, Google Scholar, and ClinicalTrials.gov and a hand search were performed up to December 2020. Randomized clinical trials (RCTs) or non-randomized clinical trials (Non-RCTs) that assessed the effects of LLLT on the orthodontic tooth movement acceleration were included. Data regarding the general information, LLLT characteristics, and outcomes were extracted. The authors performed risk of bias assessment with Cochrane Collaboration's or ROBINS-I tool. Meta-analysis was also conducted. **Results:** Five RCTs and one Non-RCT were included and 108 patients were evaluated. The LLLT characteristics presented different wavelength, power, energy density, irradiation time, and protocol duration. Five RCTs had a low risk of selection bias. Two RCTs had a low risk of performance and detection bias. All RCTs had a low risk of attrition bias, reporting bias and other bias. The meta-analysis revealed that LLLT significantly increased the orthodontic tooth movement acceleration ($p < 0.001$, Cohen's $d = 0.67$). **Conclusion:** LLLT shows positive effects on the orthodontic tooth movement acceleration.
Keywords: Orthodontic anchorage procedures, Low-level laser therapy, Stability.

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INTRODUCTION

Orthodontic treatment is long duration[1] and may result in increased risk of root resorption,[2] dental caries[3] and periodontal health problems.[4] Any method that will shorten the duration of tooth movement is desirable.[5] Many attempts have been made to reduce orthodontic treatment duration including the development of new biomechanics techniques to move teeth efficiently and find methods of accelerating tooth movement. Suggested accelerating tooth movement methods are local injections with prostaglandins, osteocalcin, corticotomy, electric current stimulation and pulsed electromagnetic field. Low-level laser irradiation has gained interest for speeding up tooth movement due to reports of successful results; even though controversy still exists.[6]When tissue receives a laser beam, there are three photobiological effects which can occur including photothermal interactions, photochemical interactions, photoacoustic interactions. Photothermal interactions, or photoablation which means the laser energy is converted into heat, leading to the removal of tissue by vaporization and super heating of tissue fluids, coagulation and hemostasis. Photochemical interactions including biostimulation are enhancement of biochemical and molecular processes that normally occur in tissues, such as healing and repair. Photoacoustic interactions occur when a pulse of laser energy produces a shockwave on hard tissue. Then hard tissue explodes and pulverized, results in an abraded crater.[7]Low-level laser units are small and inexpensive. They are available as a self-contained, handheld device, which is portable and easy to move, or as a bench-top master unit. There is no need for any cooling system and no specific safety rules such as apply to surgical laser units due to their low power output levels.[8] More recent studies have found that diode lasers of GaAlAs and GaAs have more effectiveness in higher depth of tissue penetration than HeNe(30); therefore, they should be suitable for accelerating orthodontic treatment.[9]The intervention schedule of low-level laser for accelerating orthodontic tooth movement has not yet been established.[10] However, there is information from animal studies that irradiation should be done at the start of tooth movement and be multiple rather than a single application because cells are more sensitive to laser treatment during the proliferative and early phase of differentiation which is a specific period of the cell life cycle. Therefore, multiple applications of low-level laser increase the possibility of cellular stimulation during a short window of susceptibility.[11]LLLT, when applied at correct intensity and duration, has been proven to amp up tissue healing by increasing cell proliferation (fibroblasts, osteoclasts, and osteoblasts), angiogenesis, and collagen synthesis.[12] At the molecular level, red or infrared light donates free electrons to the electron transport chain in mitochondria to curb the oxidative stress and generate more ATP.[13] This is cascade of reactions, in turn, triggers growth signalling pathways and upregulates various transcription factors,[14] with an overall increase production of growth factors.[15]

AIM OF THE PRESENT STUDY

The aim of this systematic review and meta-analysis was to assess the effects of low-level laser therapy (LLLT) on the orthodontic tooth movement acceleration.

METHODOLOGY

The reporting of this study is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and followed the guidelines in the Cochrane Handbook for Systematic Reviews of Interventions. The main search was performed in the following electronic databases: PubMed, Science Direct, Embase, Scopus, Web of Science, Cochrane Library, and LILACS. Searches were conducted from databases' date of inception until December 2020. A combination of the Boolean operators AND/OR and MeSH/non-MeSH terms was used to identify pertinent studies. The following search strategy was employed: orthodontic anchorage procedures OR orthodontic tooth movement AND lasers OR laser therapy OR low-level light therapy. The reference lists of all eligible studies were hand-searched to identify any additional relevant articles that might have been missed during the searches. The specific information included the LLLT characteristics [laser device, wavelength, irradiation site, irradiation time/frequency, power (W), energy density (J/cm2), applications], the main findings and conclusions of the included studies. The risk of bias of included randomized studies was assessment with the Cochrane Collaboration's Risk of Bias tool.[16] The criteria analyzed were (1) random sequence generation—selection bias, (2) allocation concealment— selection bias, (3) blinding of participants and personnel—performance bias, (4) blinding of outcome assessment—detection bias, (5) incomplete outcome data—attrition bias, (6) selective reporting—reporting bias, and (7) other bias. To perform the meta-analysis, the means, standard deviation (SD), and sample size of the studies cited were extracted. Because they are different scales, a meta-analysis was performed by calculating the standardized means difference (SMD) and Cohen's d estimate. A heterogeneity test and calculation of the I^2 coefficient were performed using the SPSS 25.0 ($p < 0.05$).

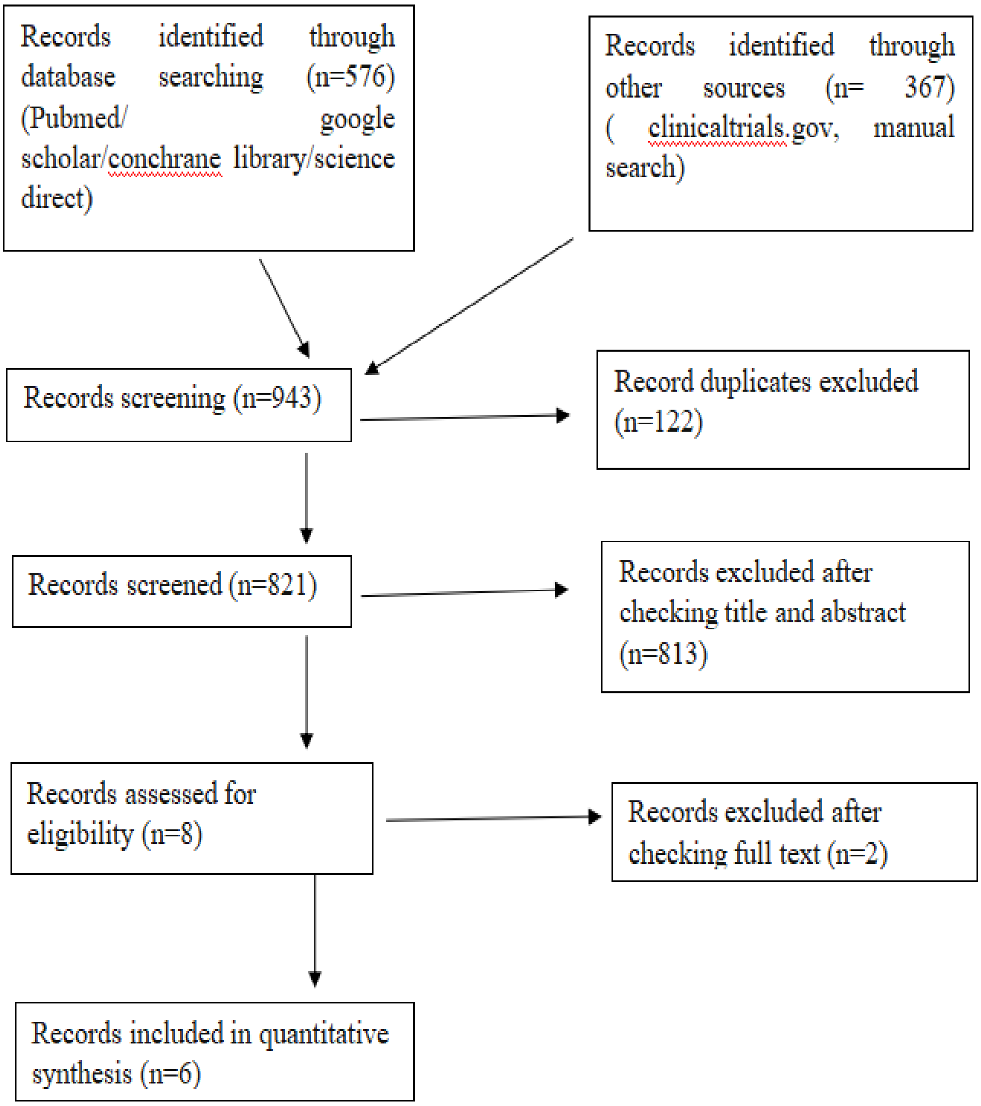
RESULTS

A total of 943 references was identified in the initial search. After removing duplicates, 821 studies remained. Based on the PICOS strategy defined in this systematic review and met-analysis, 813 studies were excluded after assessment of titles and abstracts. The full texts of eight articles were retrieved and the eligibility was assessed. At the end of the study selection, six studies were included for the qualitative and quantitative synthesis. (Figure 1)

By Cochrane Collaboration's tool, five RCTs had a low risk of selection bias (random sequence generation and allocation concealment). All RCTs had a low risk of attrition bias (incomplete outcome data), reporting bias (selective reporting), and other bias. Five studies were RCTs, only one study was Non-RCT.

Regarding the LLLT characteristics, the studies used the diode laser with wavelength varying from 618 to 940 nm, power varying from 0.1 to 1.7 W, and energy density varying from 4 to 36 J/cm2. The irradiation time per point varied from 20 s to 20 min and the applications duration varied from 14 to 30 days.

Figure 1- PRISMA flow diagram for systematic reviews and meta-analysis



DISCUSSION

Pain and rate of movement are subjective quantities and are greatly influenced by age, gender, hormones, pain threshold, and anatomic variations.[17] Ga-Al-As semiconductor diode with 940nm wavelength was used due to its deeper depth of penetration, about its low absorption coefficient in haemoglobin and water and its subsequent ability to stimulate osteoblastic activity on the target tissue.[18] Several previous authors also used Ga-Al-As with the wavelength ranging from 650nm to 860 nm. Energy output, however, varied in all the studies and led to speckled results. Research studies catering laser photo-biostimulation on orthodontic tooth movement (OTM) reveals that patients had to make some additional visits along with the regular ones for the regimen, making it difficult for them to stick to it.[19] Few previous research studies which found a single dose of LLLT to be efficient in accelerating OTM and reducing associated pain.[20]Since bone remodelling is directly related to cytokine production, LLLT stimulates bone remodelling by accelerating the production of IL-*β*, and receptor activator which is crucial for osteoclastic activity on day 2 or 3 after laser application.[21]Since the outcome of laser treatment subsequently cause from multifactor i.e. wavelength, power output, energy density, timing and frequency of irradiation. Each study used different protocol. Therefore, the specific reasons that led to effectiveness or ineffectiveness of laser treatment in each study are still unable to be concluded. Even though many studies identify energy density as the most critical factor for the success of laser treatment, there are other important factors, such as wavelength which allows tissue to absorb laser optimally, appropriate timing and frequency and total period of laser application which provide sufficient energy for stimulating cells.Note that clinical orthodontics involves a large number of interaction and random variables that can affect outcomes of controlled clinical trials in often unpredictable ways. Thus, LLLT, being one of the most recent orthodontic strategies, requires more studies and long-time frame to be considered as a routine application. Also, clinicians should consider its value to patients by comparing benefits from accelerating toothmovement with added financial costs from additional equipment and increased number of visits so that the laser can be routinely applied.The clinical trials of this systematic review and metaanalysis demonstrated that the LLLT significantly benefited the OTM. Promising results regarding this effect has already been shown in animal models.[22,23] Experimental studies facilitate the understanding of biostimulatory mechanisms of photobiomodulation on bone regeneration and inflammation. Garcez et al. demonstrated that a group of animals irradiated with LLLT showed less inflammatory infiltrate and better bone neoformation, with greater organization of collagen fibers, neovascularization, and epithelialization around the OTM.[24]

CONCLUSION

Application of LLLT at regular orthodontic visits (3 weeks intervals) accelerates OTM and decreases the pain significantly. However, more studies are required to standardize the dosage for LLLT for clinically effective OTM.

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