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Review Article **Dentistry**

Effectiveness of Photo Biomodulation in Preventing Orthodontically Induced Inflammatory Root Resorption: A Systematic Review of Randomized Controlled Trials

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Abstract

Background: Orthodontically induced inflammatory root resorption (OIIRR) remains one of the most significant adverse effects of orthodontic treatment, potentially compromising long-term tooth stability. Photo biomodulation (PBM), delivered through low-level laser or light-emitting diode (LED) therapy, has emerged as a biological adjunct proposed to mitigate this phenomenon by modulating cellular metabolism and promoting tissue repair. *Objectives:* This systematic review aimed to evaluate the effectiveness of PBM in reducing orthodontic root resorption in human subjects undergoing fixed orthodontic treatment. ***Methods:*** An electronic search was conducted in PubMed, ScienceDirect, and the Cochrane Library for randomized controlled clinical trials published between January 2017 and October 2023. Studies were included if they compared PBM-assisted orthodontic treatment with conventional or placebo protocols and quantitatively assessed root resorption crater volume using three-dimensional imaging. Risk of bias was assessed using the Cochrane RoB 2 tool, and the overall quality of evidence was evaluated through the GRADE system. ***Results:*** Five randomized controlled trials met the inclusion criteria, comprising a total of 184 participants. Two studies demonstrated a statistically significant reduction in root resorption following PBM application, while three reported no significant difference compared with controls. No adverse effects were observed. The quality of evidence was graded as moderate due to interstudy variability in irradiation parameters, wavelengths, and energy doses. ***Conclusions:*** PBM shows promising potential as a safe, non-invasive adjunct to limit orthodontically induced root resorption. However, the heterogeneity of existing protocols precludes definitive clinical recommendations. Standardized, high-quality randomized trials are needed to determine optimal dosimetry and confirm PBM's preventive and reparative role in OIIRR management.

Keywords: Photobiomodulation, Low-level laser therapy, Root resorption, Orthodontic treatment, Orthodontically induced inflammatory root resorption, Systematic review.

INTRODUCTION

Orthodontic treatment is widely recognized as an effective solution for correcting malocclusions and improving both function and aesthetics. Despite its benefits, orthodontic therapy is not without complications, the most concerning of which is orthodontically induced inflammatory root resorption (OIIRR). OIIRR is an iatrogenic process that can occur during the application of orthodontic forces and involves the progressive loss of dental root structure, primarily at the apex. Although often subclinical and limited in scope, in certain cases it may compromise tooth stability, long-term prognosis, and even treatment outcomes.

Given its multifactorial etiology, strategies to prevent or mitigate OIIRR are of particular interest in orthodontics. Traditionally, management has focused on careful biomechanical control and limiting excessive force application. However, these preventive measures are not always sufficient, and research has increasingly turned to biological adjuncts to counteract the resorptive process.

Among these adjuncts, photobiomodulation (PBM) has emerged as a promising, non-invasive therapy. PBM, delivered through low-level lasers (LLLT) or light-emitting diodes (LEDs), operates by exposing tissues to specific wavelengths of light within the red to near-infrared spectrum. This light energy is absorbed primarily by mitochondrial chromophores such as cytochrome c oxidase, triggering a cascade of cellular responses. These include enhanced adenosine triphosphate (ATP) production, modulation of reactive oxygen species (ROS), and release of nitric oxide, which collectively promote cell proliferation, angiogenesis, and tissue remodeling.

In orthodontics, PBM has been widely studied for its ability to accelerate tooth movement and alleviate pain. Its application in minimizing root resorption, however, remains less clearly defined. Experimental evidence suggests that PBM may exert both preventive effects, by reducing mechanical stress and inflammation in the periodontal ligament, and reparative effects, by stimulating cement oblast proliferation and deposition of secondary cementum. Yet, clinical studies have produced mixed results, with some reporting significant reductions in root resorption volume and others finding no measurable difference compared to controls.

This inconsistency underscores the need for a comprehensive evaluation of the current evidence. By systematically reviewing randomized controlled trials (RCTs), this work aims to clarify the potential role of PBM in the management of OIIRR. Ultimately, a better understanding of PBM's efficacy could help clinicians integrate this adjunctive modality into orthodontic practice, improving patient safety and outcomes while reducing one of the most feared complications of fixed appliance therapy.

MATERIALS AND METHODS

Protocol and registration:

The Cochrane Handbook for Systematic Reviews of Interventions mentioned using the PICOS framework as a model for developing a review question, thus ensures that the relevant components of the question are well defined. [2]

The eligibility criteria of this review followed the PICOS criteria as such:

- ✓ **Population** = Orthodontic patients receiving photobiomodulation therapy (PBM).
- ✓ **Intervention** = PBM used as an aid intervention in fixed orthodontic treatment.
- ✓ **Compared with** = Control groups receiving fixed orthodontic treatment without any other interventions and/or placebo group receiving simulated PBM treatment.
- ✓ **Outcome of interest** = orthodontic root resorption crater volume
- ✓ **Study type** = Randomized controlled clinical trial (parallel group or split mouth design).

Inclusion criteria :

The included articles met the following criteria:

- ✓ Articles in English dating from 01/01/2017 to 15/10/2023.
- ✓ The articles must meet all PICOS criteria with the design of randomized clinical trials (RCTs) conducted on humans (parallel group or split mouth design).
- ✓ Human teeth subjected to orthodontic force application in any direction.
- ✓ PBM interventions conducted with LEDs or LLLs equipment.
- ✓ Studies presenting the parameters of PBM and the individual characteristics of patients.
- ✓ Outcome variables were defined as Overall treatment time, orthodontic tooth movement rate (tooth displacement in a determined period of time), pain score perception, orthodontic root resorption crater volume.

Exclusion criteria:

- ✓ Non-randomized clinical trials
- ✓ In-vitro studies or animal studies
- ✓ Studies without a control/comparison group
- ✓ Review articles, case reports, case series, and letters to editor.
- ✓ Studies available only in languages other than English.
- ✓ Studies that included fewer than 10 patient or hemiarch (quadrant) per group.
- ✓ Patients of studies exposed to previous orthodontic treatment.
- ✓ Studies involving participants suffering from metabolic disorders, or taking medications impeding or hastening tooth movement.
- ✓ Studies involving participants who had a high caries index or periodontal disease.
- ✓ Studies that used high-level laser or red laser.

Information sources and search strategy

The review authors performed an extensive electronic search for randomized controlled trials realized on humans up to October 15, 2023, in three databases: PubMed, Science Direct, and Cochrane

Library. The search strategies employed are outlined in Table 1.

Table I: search strategies in the three databases

Database	Search strategy
PubMed	("low-level laser" OR "low-level laser therapy" OR photobiomodulation) AND orthodontic* AND root resorption
ScienceDirect	("low-level laser" OR "low-level laser therapy" OR photobiomodulation) AND orthodontic AND root resorption
Cochrane Library	("low-level laser" OR "low-level laser therapy" OR photobiomodulation) AND orthodontic* AND root resorption

All articles and manuscripts published in English or with English translations available were incorporated in the search and only articles published from 01-01-2017 were selected. The search was complemented by a manual review of the references of the studies included.

Data extraction

Titles and abstracts were selected independently by the investigators to verify their eligibility. In cases of discrepancy, consensus was obtained by discussion. The same reviewers then examined the references that appeared to meet the inclusion criteria in their entirety.

The information regarding the selected studies was recorded using three data extraction forms specifically created for this purpose to systematically and uniformly analyze and compare each selected article.

A first form for the extraction of the following data: author and date, total number of patients / Teeth, number of subjects in PBM group, number of subjects in control group, mean age of patients, the orthodontic mechanics and the clinical assessment used in the trial, and the principal outcome of the trial.

A second form for the extraction of light parameters data: the equipment used, wavelength, irradiation points, dose of energy and the phototherapy session protocol.

A third and final form for the extraction of: the mean values of the main outcome, the results and the conclusion of each article.

Then, the gathered information was grouped and synthesized into tables for discussion and analysis to address the main question of the research.

Risk of bais asses ment

The assessment of the risk of bias in the included studies was conducted using Version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2). RoB 2 is the recommended tool for evaluating the risk of bias in randomized trials included in Cochrane Reviews.[1] The tool is organized into five domains that identify potential sources of bias in the study results, the five domains are:

1. Bias arising from the randomization process.
2. Bias due to deviations from intended interventions.
3. Bias due to missing outcome data.
4. Bias in the measurement of the outcome.
5. Bias in the selection of the reported result.

Within each domain, a set of questions known as 'signalling questions' is designed to gather information relevant to the risk of bias. An algorithm utilizes the responses to these questions to generate a proposed judgment regarding the risk of bias for each domain. This judgment can be categorized as 'Low' or 'High' risk of bias or expressed as 'Some concerns.' [1]

The reviewers independently assessed the risk of bias using an excel tool designed to implement RoB 2, and the differences between the reviewers were resolved by discussion.

Level of Evidence

The evaluation of the level of evidence was carried out utilizing the Grading of Recommendation Assessment, Development, and Evaluation (GRADE) system by the two reviewers independently.

The GRADE system principles were applied to assess the overall quality of the body of evidence associated with the outcome. To facilitate this assessment, a "Summary of Findings" (SoF) table was constructed using the GRADEpro GDT software available at http://gdt.guidelinedevelopment.org.

The evaluation of the body of evidence considered factors such as the overall risk of bias in the included studies, directness of the evidence, inconsistency of results, precision of estimates, risk of publication bias, and the magnitude of the effect. Depending on the severity, the quality of evidence can be downgraded by one or two levels for each aspect. We categorized the quality of the body of evidence for each primary outcome as high, moderate, low, or very low.

RESULTS

Study selection:

The electronic search retrieved 527 results from all the databases.

451 results remained after removal of duplicates, which were then screened by titles and abstracts. 56 of those were of the desired study design. Six articles were not accessible for full text screening and 45 articles were excluded for not matching the eligibility criteria, which left us with a total of five articles to be included in this systematic review.

A flowchart of the article selection process for each stage of the review is presented in Figure 1.

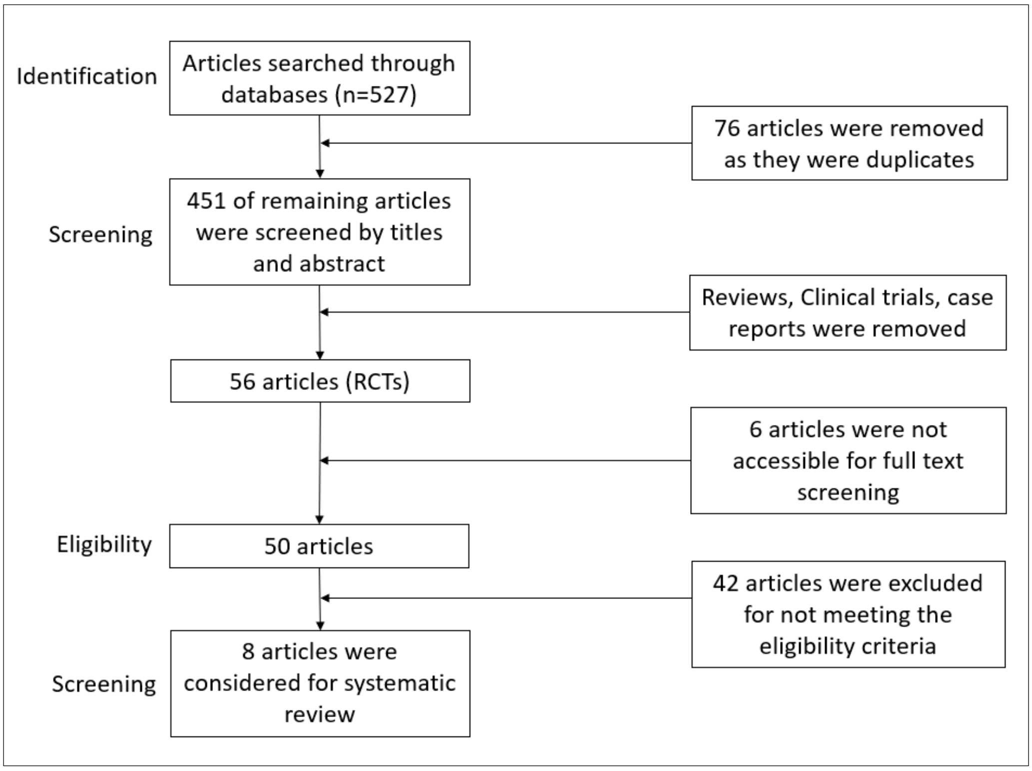

Figure 1: Flowchart of the article's selection process

Caractéristiques of inclue studieuse

Fourteen relevant publications assessing the effectiveness of PBM in orthodontic tooth movement pain management were identified as eligible according to the predefined inclusion criteria for this review.

The gathered data was grouped into the tables II, III and IV below:

Table II: Clinical characteristics of the RCTs exploring orthodontic root resorption management

author and date	patients / Teeth	number in PBM group	number in control group	mean age	orthodontic mechanics and clinical assessement	outcome
Doreen Ng *et al.*, 2017 [3]	20 patients 40 teeth	20	20	Males: 16.4 Females: 16.7	The participants (Patients who required upper first premolar extractions for orthodontic treatment) had partial fixed appliances placed bilaterally on the MaxFPs and first molars. Self-ligating 0.022″ DAMON brackets and tubes were used. Buccaltipping forces (150 g) were applied to the MaxFPs using 0.017″ × 0.025″” Beta III Titanium cantilever springs for 28 days to induce orthodontic root resorption	Difference in root resorption crater volume between LLLT and placebo-laser.

author and date	patients / Teeth	number in PBM group	number in control group	mean age	orthodontic mechanics and clinical assessement	outcome
Merve Goymen *et al.*, 2019 [4]	30 patients	10 laser 10 LED	10	16.27	Prior to initiating orthodontic treatment in patient groups, maxillary right first premolar and first molar teeth were bonded with 0.022 slot MBT brackets and tubes. A 150-g orthodontic force (buccal tipping) was applied to the maxillary right first premolar tooth. A cantilever spring with 0.017 × 0.025 Beta Titanium wire was used for force application.	total root resorption per root surface
Nida Nayyer 2020 [5]	22 patients 44 teeth	22	22		the first premolars were subjected to 150 g buccal force using a 0.019 0.025 beta-titanium alloy cantilever spring assembly extending from first molar to first premolar, A 0.036 stainless steel transpalatal arch was cemented to control the reactionary force on the molars	Resorption crater volume
John Sambevski *et al.*, 2022 [6]	20 patients 40 teeth	20	20	15 years 6 months	Self-ligating 0.022-in brackets were bonded on maxillary first premolars and molars. Buccal tipping force of 150 g was applied to each maxillary first premolar using a 0.0175 × 0.025 Beta III titanium cantilever spring which connected the maxillary first permanent molars and first premolars.	evaluation of root resorption crater volumes
Amer Nasser *et al.*, 2023 [7]	30	15	15	22.4	fixed orthodontic appliances of the MBT prescription and 0.022-inch slot height were attached to the upper incisors of patients with deep overbite. Soldered hooks were placed between the central and lateral incisors on each side. After completing the leveling and alignment stage, self-drilling mini-implants were inserted between the roots of the upper central incisors and the lateral incisors from the labial aspect at the gingival-mucosaljunction on both sides. The loading of these mini-implants was accomplished immediately following insertion with a force of 40 g, on each side through an NiTi locking spring extending from the head of the mini-implants to the hooks welded on the archwire. The spring strength was adjusted every four weeks until the end of the intrusion stage, which was determined by reaching a normal overbite.	Volumetric assessment of root resorption

Table III: Phototherapy parameters of the RCTs exploring orthodontic root resorption management

author and date	equipement	wave length	irradiation points	energy density per session	laser session
Doreen Ng *et al.*, 2017 [3]	diode laser	808-nm	The laser and placebo-laser was applied to the mucosal surface along the MFP root at four points on the buccal and four points on the palatal surface. The laser was applied at the following points: 1. Apex; 2. Middle third (centre of the root); 3. Cervical third (mesial); and 4. Cervical third (distal).	1.6 J per point	LLLT was applied to the MFPs for the first 4 days (days 0, 1, 2, and 3) and then weekly (day 7, 14, and 21) during the 28 day experimental period. There were a total of seven laser applications.
Merve Goymen *et al.*, 2019 [4]	*GaAlAs diode laser device *LED device (OrthoPulse)	810-nm 850 nm			*For Group 1: diode laser application was performed with laser device at 0, 3, 7, 14, 21, and 28 days to 8 J/cm2. *For Group 2: LED application was applied daily for 10 min per day in accordance with the manufacturer's instructions.
Nida Nayyer 2020 [5]	Indium-gallium-arsenide (InGaAs)	980 nm	It was aimed at five points buccally and five palatally around the first premolar root : two in the cervical third, two in the middle third and one at the apex. Each point was irradiated for 10 seconds.	10 J energy per tooth	The laser was applied in 6 sessions during the 28-day time period,starting on the day of force application (day 0) and on days 3, 7, 11, 15 and 28
John Sambevski *et al.*, 2022 [6]	OrthoPulse™ device	850 nm		60 mW/cm2	5 minutes/day for 28 days
Amer Nasser *et al.*, 2023 [7]	semiconductor gallium-aluminum-arsenide (Ga-Al-As) diode laser	808 nm	The laser was applied to the root of each of the upper incisors at eight points (four points from the labial side and four points from the palatal side) with a total application time of 128 seconds for each tooth The irradiation head was placed in the center of each of the apical and middle thirds and the mesial and distal of the cervical third of the root.	4 Joules/point	The laser was applied on the first day of the upper incisor intrusion (T1), then on days 3, 7, and 14 of the first month. In the second month, the laser was applied every 15 days,

Table IV: Findings of the RCTs exploring orthodontic root resorption management

Author And Date	Outcome (Mean ± Sd)		Results	Conclusion
	Test	Control		
Doreen Ng *et al.*, 2017 [3]	0.381 mm3	0.495 mm3	There was significantly less root resorption crater volume on the laser side compared to the placebo-laser side.	LLLT seems promising in preventing or reducing orthodontic root resorption during the initial stages of orthodontic force application.
Merve Goymen *et al.*, 2019 [4]	*0.42 ± 0.07 mm3 for Group 1 *0.25 ± 0.03 mm3 for Group 2	0.40 ± 0.06 mm3	No significant difference was found between the groups in terms of total crater volumes. However, there is a tendency for Group 2 to have few resorption value.	Within the limitations of this study, no significant difference in root resorption was found between groups. However there was still a tendency that photobiomodulation might lead to less root resorption
Nida Nayyer *et al.*, 2020 [5]	239.47 ± 85.75 10^6 mm3	395.91 ± 117.12 10^6 mm3	the results showed statistically significant reduction in The mean total volume of resorption craters per tooth ($P < 0.05$).	Photobiomodulation is a useful therapy for reduction of the occurrence of external root resorption induced during orthodontic tooth movement.
John Sambevski *et al.*, 2022 [6]	0.216 mm3	0.284 mm3	PBM resulted in 0.068 mm3 or 24% less root resorption compared with regular orthodontic tooth movement. However, this difference was not statistically significant ($P = 0.308$).	This 28-day pilot randomized split-mouth controlled trial showed that using OrthoPulse for 5 minutes/day for the application of LED-mediated PBM is not associated with any difference in orthodontic root resorption when the maxillary first premolars are subjected to a 150 g buccal tipping force.
Amer Nasser *et al.*, 2023 [7]	U1 : -19.52 U2 : -20.43	U1 : -21.93 U2 : -23.06	The difference between the two groups was not statistically significant in each central and lateral incisor volume root (P=0.345 and 0.263 for U1 and U2, respectively).	The low-level laser irradiation using the current protocol did not significantly affect the amount of root resorption induced by incisor intrusion in the experimental group compared to the control group.

Risk of bias of included studies

Given the inherent characteristics of these studies, achieving blinding of both patients and operators was nearly impractical, as the laser and the simulation (placebo) are typically administered in the same session. Consequently, the absence of single or double blinding was not deemed to significantly affect the assessment of the risk of bias in all the studies.

The risk of bias of the included RCTs is shown in Figure 2.

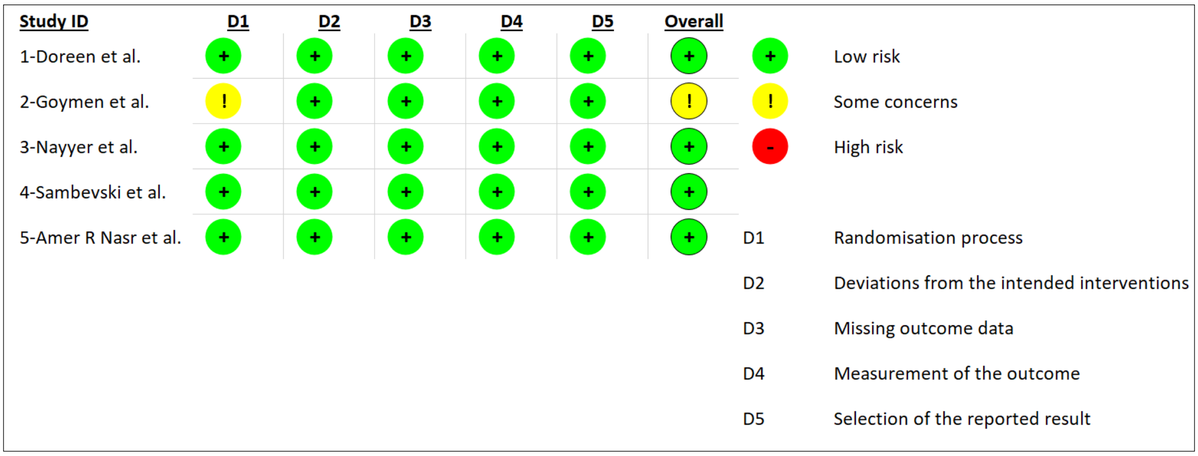

Figure 2: Risk-of-bias graph of the studies exploring pain management

Out of the total eight RCTs, two trials by Prasad *et al.*, and Brito *et al.*, were assessed as having “some concerns” in the risk of biais, the rest were defined as having a low risk of biais.

Despite the exclusive inclusion of randomized studies, it was noted that the trials conducted by Prasad *et al.*, and Brito *et al.*, did not provide explicit descriptions of how the randomization sequence was generated.

None of the studies included in the analysis reported "incomplete outcome data" resulting from the withdrawal of a substantial number of participants.

Quality of Evidence Summary

In our systematic review, we investigated one main outcome which is resorption crater volume. A crucial aspect of our analysis involved assigning a quality rating to the body of evidence for the outcome across the included studies. To accomplish this, we employed the GRADE approach, a systematic method for evaluating the quality of evidence.

The GRADE approach initiates the assessment by considering the study design, distinguishing between trials and observational studies. Subsequently, it delves into five potential factors that might warrant a downgrade in the quality of evidence. These factors include the risk of bias, inconsistency, indirectness, imprecision, and publication bias.

While all the studies encompassed in our analysis adhered to the randomized controlled trial design, methodological concerns emerged that restricted the overall quality of evidence pertaining to the outcome.

The quality of evidence underwent a downgrade primarily attributed to the observed inconsistencies in the results across studies. Significant heterogeneity was noted among these studies, contributing to a less robust and coherent body of evidence for root resorption.

Consequently, our final assessment categorized our outcome as presenting a moderate quality of evidence as detailed in Table V.

The findings from our research are carefully compiled and displayed in a detailed Summary of Findings table (table VI), utilizing the software Garde Pro GDT. This table is designed to be a central element, capturing the core essence of our research efforts with accuracy and clarity.

Table V: Quality of evidence assessment

Certainty assessment							**Certainty**
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	
root resorption							
5	randomised trials	not serious	serious[b]	not serious	not serious	none	⊕⊕⊕◯ Moderate

Table VI: Summary of Findings table

Photobiomodulation compared to non-photobiomodulation for fixed orthodontic treatment		
Patient or population: fixed orthodontic treatment		
Setting:		
Intervention: photobiomodulation		
Comparison: non-photobiomodulation		
Outcome № of participants (studies)	Impact	Certainty
root resorption № of participants: 184 (5 RCTs)	Only two of these studies, demonstrated a noteworthy decrease in Orthodontically Induced Root Resorption (OIRR) with the application of photobiomodulation (PBM). Conversely, the other three studies indicated no significant disparity in resorption crater volume between the groups subjected to PBM and the control groups.	⊕⊕⊕◯ Moderate
GRADE Working Group grades of evidence High certainty: we are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.		

DISCUSSION

Broad concepts

In 2002, Brezniak and Wassertein coined the term 'orthodontically induced inflammatory root resorption' (OIIRR) to characterize a pathological occurrence associated with orthodontic tooth movement. This phenomenon involves the depletion of substances from the dentine or cementum layer of the tooth root [8]. OIIRR stands apart from other forms of root resorption due to its highly intricate, sterile inflammatory process. This process encompasses various factors, including orthodontic forces, tooth root morphology, alveolar bone, the surrounding matrix, and specific recognized biological messengers [9].

Orthodontic tooth movement (OTM) is a well-coordinated procedure involving efficient bone remodeling [10]. When a consistent orthodontic force is applied to a tooth, there is a simultaneous occurrence of bone resorption on the compression side and deposition on the tension side of the periodontal ligament (PDL) to facilitate OTM [11]. However, if the force surpasses the blood pressure in the capillary bed, it obstructs the vasculature, leading to hyalinization (sterile necrosis) of the PDL and the surrounding alveolar bone on the compression side [12]. To sustain OTM, the hyalinization sites release various biomolecules that attract macrophage-like cells, multinucleated cells, osteoclasts, and cementoclasts/odontoclasts to resorb the necrotic PDL [13]. Cementoclasts/odontoclasts are large, multinucleated cells with a phenotype resembling that of osteoclasts. Unlike osteoclasts, however, these cells primarily participate in the resorption of dental tissue [14].

The resorption of the necrotic periodontal ligament (PDL) can harm the adjacent outer layer of the root, known as the cementoblast layer covering the cementoid. This results in an exposed cemental surface vulnerable to targeting by odontoclast cells, triggering inflammatory events on the root surface similar to bone resorption [15]. The resorption persists until there are no remaining hyaline tissues and/or the orthodontic force is halted. Consequently, discontinuing the orthodontic force enables a natural process where the reversal of resorption and the repair of the cementum can take place [16]. Every orthodontic treatment will inevitably lead to some form of root resorption, constituting an unavoidable side effect of orthodontic procedures. Findings from a prospective study revealed that 94% of patients undergoing orthodontic treatment exhibited root resorption exceeding 1 mm [17]. The extent of root resorption is unpredictable and is influenced by various factors, including individual biological variables, genetics, and mechanical factors [18]. These factors may be associated with root morphology, abnormalities, endodontic procedures, the severity of malocclusion, and instances of trauma. Weltman *et al.*, discussed systemic and genetic factors such as hormone deficiency, hypothyroidism, and hypopituitarism in 2010. Mechanical factors pertain to aspects of orthodontic treatments, including the direction and magnitude of applied force, treatment techniques, and the type of appliances utilized [19].

Periapical radiographs are commonly employed for measuring tooth length and estimating root resorption; however, errors may arise due to angulation error, linear error, and film bending. Additionally, the presence of overlapping in two-dimensional radiographs can make it challenging to identify certain anatomical points [20]. Hence, the use of cone beam computed tomography (CBCT) systems (fig. 3) is considered more reliable.

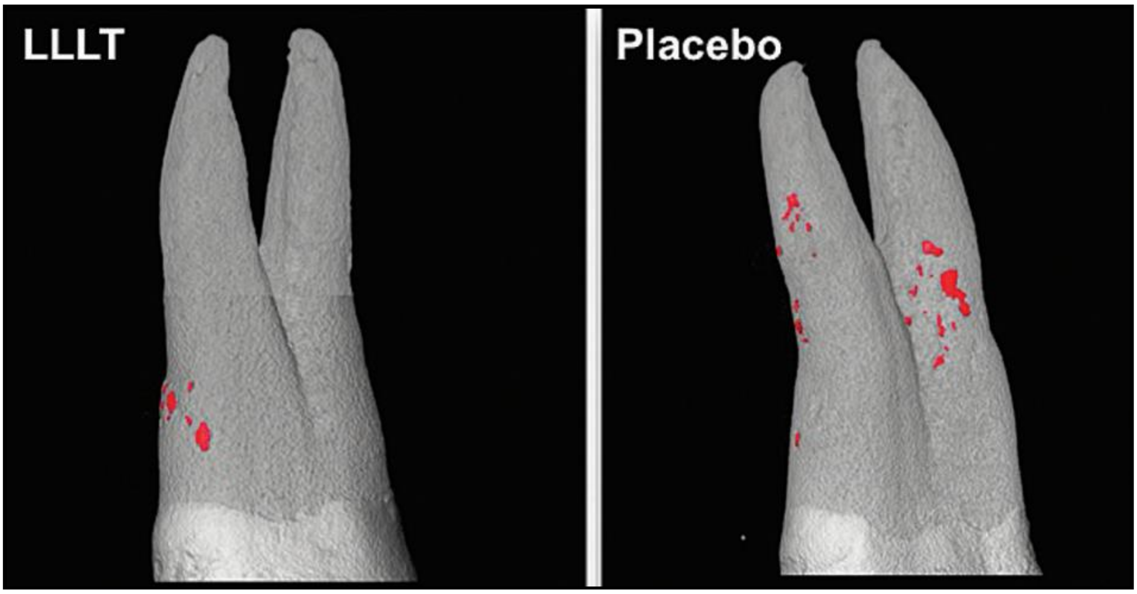

Figure 3: 3D reconstruction of LLLT and placebo-laser specimen showing root resorption craters (in red) in the Doreen Ng *et al.*, trial

A study conducted by Sherrard *et al.*,[21] utilized CBCT scans of seven fresh porcine heads, comparing the results with the actual tooth length after meticulous removal of surrounding bone. The findings revealed that root length measured by CBCT did not significantly differ from the actual tooth length. Furthermore, the study demonstrated that the method error in assessing root length was twice as high for periapical radiographs compared to the CBCT method.

The functional capacity of teeth may be compromised due to root resorption, particularly when combined with periodontal disease [22]. As a result, addressing iatrogenic root resorption has become a primary goal for researchers worldwide. Several strategies, including reducing treatment duration, employing controlled mechanics, or considering individual susceptibility factors such as systemic disorders, genetics, prior trauma, or age, have been recognized for their role in decreasing the occurrence of orthodontically induced inflammatory root resorption (OIIRR) [140]. Recent non-invasive methods, such as low-level laser, light-emitting diodes, and low-intensity pulsed ultrasound (LIPUS), are currently under investigation for similar purposes [23].

While the literature supports the positive impact of photobiomodulation on tooth movement, its correlation with tooth root resorption is a relatively new area of exploration. The biological foundation for accelerating orthodontic tooth movement through this approach involves, as previously highlighted in this thesis, the growth of fibroblasts and collagen fibers, the regeneration of blood vessels, and the stimulation of neuronal growth. However, there remains uncertainty about the root's ability to adapt to this accelerated bone remodeling process.

Numerous animal experiments have been conducted to examine the impact of Low-Level Laser Therapy (LLLT) on orthodontic root resorption. In their rat study, Ekizer *et al.,* observed an inhibitory effect of LED applications on Orthodontically Induced Inflammatory Root Resorption (OIIRR). Similarly, through an animal study, Higashi *et al.,* concluded that LED application was directed at preventing OIIRR. Fonseca *et al.,* proposed that LED application proved effective in the remodeling of periodontal tissue, leading to a reduction in inflammation and root resorption.

Until 2017, the orthodontic literature had minimal evidence regarding the potential side effects of Low-Level Laser Therapy (LLLT) on Orthodontically Induced Inflammatory Root Resorption (OIIRR) in humans. Only two human studies, with no reported adverse outcomes, had explored the impact of LLLT on orthodontic root resorption [24, 25]. The prevailing consensus from these limited human studies suggested that LLLT did not lead to greater root resorption compared to conventional orthodontic treatment [26, 27]. However, a notable limitation of these studies was the use of two-dimensional periapical radiographs for quantifying root resorption, raising concerns about the accuracy of the findings. As highlighted earlier, a more precise method for evaluating root resorption involves the application of micro-computed tomography (Micro-CT), enabling the three-dimensional identification of resorption craters [28].

In a 2019 systematic review conducted by Michelogiannikis, analyzing both animal and human studies, the impact of photobiomodulation on root resorption was deemed uncertain [29]. Also, there is skepticism regarding the applicability of conclusions drawn from animal studies to humans, given the significant difference in tooth size between rats and humans.

Therefore, to ensure coherence in drawing conclusions, the current systematic review specifically focused on human participants.

ANALYSIS FINDINGS DISCUSSION

Among the trials included in this analysis, Doreen Ng et al., Merve Goymen *et al.,* Nida Nayyer et al., and John Sambevski *et al.,* employed a buccal tipping force of 150 grams using a cantilever spring on human premolars. Amer Nasser *et al.,* applied standard clinical forces for alignment, along with an additional 80 grams of intrusive forces through a NiTi locking spring.

In fact, in 2013 Consolaro asserted that if a study aimed to explore the impact of phototherapy on the severity of root resorption, the applied forces in the experiment should inevitably induce lesions on the cementoblast layer, eliminating root protection [26]. Yet, determining a precise threshold force for standardizing trials remains challenging. However, previous studies observed sufficient root resorption in human premolars within 21–28 days with a force ranging from 120 to 150 grams [29].

In all five studies, a consistent methodology was employed, utilizing three-dimensional computed tomography and assessing resorption crater volumes as the main outcome. Notably, only two of these studies, conducted by Doreen Ng *et al.,* and Nida Nayyer *et al.,* demonstrated a noteworthy decrease in Orthodontically Induced Root Resorption (OIRR) with the application of photobiomodulation (PBM). Conversely, the other three studies indicated no significant disparity in resorption crater volume between the groups subjected to PBM and the control groups. It is crucial to highlight that none of these studies suggested that PBM might contribute to an increase in Orthodontically Induced Root Resorption (OIRR).

Both Merve Goymen *et al.,* and Amer Nasser *et al.,* studies shared a common limitation: the absence of a split-mouth method design in the trial. The split-mouth design is crucial for enhancing study accuracy by eliminating inter-individual differences between subjects. The results of both studies indicated inter-subject variability in terms of root resorption, suggesting that individuals could not be fully homogenized.

The variation in results across the studies included in this analysis may be attributed to several factors that can impact the effectiveness of light therapy in general. Photobiomodulation exhibits diverse effects, and depending on the light parameters applied, it can produce both stimulating and inhibitory responses. Studies demonstrating a positive impact of PBM typically utilized energy densities of 4 J/cm2. However, studies conducted by Merve Goymen *et al.*, John Sambevski *et al.*, and Amer Nasser *et al.*, which employed energy densities of 8 J/cm2, 18 J/cm2, and 4 J/point, respectively, did not report positive results. Moreover, the extent to which the light source penetrates tissues and reaches the periodontium is influenced by various factors, including tissue thickness, pigmentation, keratinization, hydration, maturity, and the depth of the roots within the alveolar housing [30]. This introduces challenges in determining the optimal light parameters to mitigate root resorption, as there is likely to be substantial variability in the amount of light energy loss and tissue penetration among patients with different soft and hard tissue characteristics. Adjustments for these variations are essential.

While specific PBM dose recommendations for root resorption have not been clearly defined, the World Association for Laser Therapy (WALT) has made an attempt to provide guidelines for inflammatory pathologies. It suggests a range of 1–16 J as the minimum total dose for wavelengths 780–820 nm and 904 nm [30]. Currently, there is a lack of consensus within the orthodontic community regarding the efficacy of Photobiomodulation (PBM) in reducing root resorption (RR). It remains uncertain whether the observed decrease in root resorption on the laser-treated side is a result of the preventive effects of Low-Level Laser Therapy (LLLT) or if it stems from its reparative potential.

Based on the existing information, it can be conjectured that photobiomodulation may operate through multiple complex mechanisms. It could provide a preventive effect by preserving the outermost cementum layer through enhanced bone remodeling and the alleviation of compressive stresses in the Periodontal Ligament (PDL). PBM may reduce stress on the unmineralized outermost protective barrier, known as cementoid or pre-cementum, which is crucial for maintaining the integrity of root tissues, by accelerating the process of alveolar bone resorption on the compression side.

Another hypothesis involves the reparative effect of LLLT on root resorption. Studies indicate that LLLT stimulates the proliferation of cementoblasts and fibroblasts, enhancing the reparative process through secondary cementum formation, new capillary formation, and a reduction in osteoclastic activity due to a decrease in the RANKL/OPG ratio [31]. However, it's essential to acknowledge the possibility of PBM inducing root resorption, as the same cellular activation processes involved in bone resorption may come into play.

CONCLUSION

Photobiomodulation (PBM) demonstrates promising potential as an adjunctive approach for mitigating orthodontically induced inflammatory root resorption (OIIRR). Evidence from randomized controlled trials indicates a possible protective effect on root structure, although findings remain inconsistent across studies. Variability in irradiation parameters, wavelengths, and energy doses likely contributes to these discrepancies.

Despite the absence of reported adverse effects, the current evidence is insufficient to establish standardized clinical protocols. Further well-designed, large-scale randomized trials are warranted to clarify the biological mechanisms, optimize dosimetry, and confirm PBM’s preventive and reparative potential in orthodontic root resorption.

REFERENCES

- Langendam MW, Akl EA, Dahm P, Glasziou P, Guyatt G, Schünemann HJ. Assessing and presenting summaries of evidence in Cochrane Reviews. *Syst Rev 2013; 2:81.*
- Liberati A, Altman DG, Tetzlaff J *et al.*,The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ 2009;339: b2700.*
- Ng D, Chan AK, Papadopoulou AK, Dalci O, Petocz P, Darendeliler MA. The effect of low-level laser therapy on orthodontically induced root resorption: a pilot double blind randomized controlled trial. *Eur J Orthod 2018;40(3):317-25.*
- Goymen M, Gulec A. Effect of photobiomodulation therapies on the root resorption associated with orthodontic forces: a pilot study using micro computed tomography. *Clin Oral Investig 2020;24(4):1431-8.*
- Nayyer N, Tripathi T, Rai P, Kanase A. Effect of photobiomodulation on external root resorption during orthodontic tooth movement - a randomized controlled trial. *Int Orthod 2021;19(2):197-206.*
- Sambevski J, Papadopoulou AK, Foley M *et al.*, Physical properties of root cementum: Part 29. The effects of LED-mediated photobiomodulation on orthodontically induced root resorption and pain: a pilot split-mouth randomized controlled trial. *Eur J Orthod 2022;44(6):650-8.*

- Nasser AR, Sultan K, Hajeer MY, Hamadah O. Investigating the effectiveness of low-level laser in reducing root resorption of the upper incisors during intrusion movement using mini-implants in adult patients with deep overbite: A randomized controlled clinical trial. *Cureus 2023;15(2):e35381.*
- Rohaya MA, Noor Ayuni A, Shahrul Hisham ZA. An insight into risk factors for root resorption during orthodontic treatment. *J Med Sci 2017 ;17 :1-9.*
- Li Y, Jacox LA, Little SH, Ko CC. Orthodontic tooth movement: The biology and clinical implications. *Kaohsiung J Med Sci 2018;34(4):207-14.*
- Krishnan V. Root resorption with orthodontic mechanics: Pertinent areas revisited. *Aust Dent J 201762(S1):71-7.*
- Yazid F, Teh Y, Ashari A, Ariffin SH , Wahab RM A. Detection methods of orthodontically induced inflammatory root resorption (OIIRR): a review. *Aust Orthod J 2020;36(1):101-7.*
- Brudvik P, Rygh P. The repair of orthodontic root resorption: an ultrastructural study. *Eur J Orthod 1995;17(3):189-98.*
- Korkmaz Y, Puladi B, Galler K *et al.*, Inflammation in the Human Periodontium Induces Downregulation of the α1- and β1-Subunits of the sGC in Cementoclasts. *Int J Mol Sci 2021;22(2):539.*
- Reitan K. Some factors determining the evaluation of forces in orthodontics. *Am J Orthod 1957;43(1):32-45.*
- Brudvik P, Rygh P. Transition and determinants of orthodontic root resorption-repair sequence. *Eur J Orthod 1995;17(3):177-88.*
- Lund H, Grondahl K, Hansen K, Grondahl H. Apical root resorption during orthodontic treatment A prospective study using cone beam CT. *Angle Orthod 2012;82:480-7.*
- Linge L, Linge BO. Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment. *Am J Orthod Dentofacial Orthop 1991; 99:35-43.*
- Weiland F. Constant versus dissipating forces in orthodontics: the effect on initial tooth movement and root resorption. *Eur J Orthod*
- Westphalen VP, Gomes de Moraes I, Westphalen FH, Martins WD, Souza PH. Conventional and digital radiographic methods in the detection of simulated external root resorptions: a comparative study. *Dentomaxillofac Radiol 2004; 33:233-5.*
- Sherrard JF, Rossouw PE, Benson BW, Carrillo R, Buschang PH. Accuracy and reliability of tooth and root lengths measured on conebeam computed tomographs. *Am J Orthod Dentofacial Orthop 2010; 137:100-8.*
- Jonsson A, Malmgren O, Levander E. Long-term follow-up of tooth mobility in maxillary incisors with orthodontically induced apical root resorption. *Eur J Orthod 2007;29(5):482-7.*
- Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part II: the clinical aspects. *Angle Orthod 2002;72(2):180-4.*
- Raza H, Major PW, Dederich D, El-Bialy T. Effect of low-intensity pulsed ultrasound on orthodontically induced root resorption caused by torque: a prospective, doubleblind, controlled clinical trial. *Angle Orthod 2016;86(4):550-7.*
- Cruz DR, Kohara EK, Ribeiro MS, Wetter NU. Effects of low-intensity laser therapy on the orthodontic movement velocity of human teeth: a preliminary study. *Lasers Surg Med 2004;35(2):117-20.*
- Sousa MV, Scanavini MA, Sannomiya EK, Velasco LG, Angelieri F. Influence of low-level laser on the speed of orthodontic movement. *Photomed Laser Surg 2011;29(3):191-6.*
- Michelogiannakis D, Al-Shammery D, Akram Z, Rossouw PE, Javed F, Romanos GE. Influence of low-level laser therapy on orthodontically-induced inflammatory root resorption. A systematic review. *Arch Oral Biol 2019; 100:1-13.*
- Consolaro A. Effects of medications and laser on induced tooth movement and associated root resorption: four key points. *Dental Press J Orthod 2013;18(2):4-7.*
- Reitan K. Initial tissue behaviour during apical root resorption. *Angle Orthod 1974; 44:68-82.*
- Keković V, Schicho K, Figl M *et al.*, Light distribution of 635 nm LED for PBM treatments in the maxillofacial region. *Oral Maxillofac Surg Cases* 2021; 7:100208.
- World Association of Laser Therapy (2010) Recommended treatment doses for low level laser therapy [Online]. *Available at: waltza.co.za/wp-content/uploads/2012/08/Dose_table_904nm_for_Low_Level_Laser_Therapy_WALT-2010.pdf*
- Altan AB, Bicakci AA, Avunduk MC, Esen H. The effect of dosage on the efficiency of LLLT in new bone formation at the expanded suture in rats. *Lasers Med Sci 2015;30(1):255-62.*