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Review Article

Effectiveness of lasers in preventing white spot lesions in patients undergoing fixed orthodontic treatment- A systematic review

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Abstract

Objectives: To evaluate and compare the in vivo efficacy of various laser modalities in preventing white spot lesions (WSLs) in orthodontic patients with fixed appliances

Materials and Methods: We searched four online databases (Cochrane Library, PubMed Central, Science Direct, and Ovid®) up to August 31, 2024, identifying 1,605 articles. Eleven papers satisfied the eligibility criteria and were incorporated into the qualitative synthesis. The potential for bias in the chosen studies was assessed utilizing the Cochrane ROB-2 tool. PROSPERO- CRD2020212233

Results: Among the 11 included articles (9 randomized controlled trials and two clinical trials), four studies focused on argon lasers, four on CO2 lasers, one on both CO2 and Erbium-Chromium: Yttrium-Scandium-Gallium-Garnet lasers (Er, Cr: YSGG) in separate groups, one on Neodymium-doped yttrium Aluminum garnet (Nd), and one on a diode laser. Overall, the studies exhibited a moderate risk of bias. Laser treatments, particularly CO_2, Er: YAG, and Nd: YAG lasers, effectively prevent WSLS, enamel demineralisation, and caries while improving microhardness. Combining lasers with fluoride boosts their protective effects, especially in high-risk groups like children with partially erupted molars. CO_2 lasers demonstrate consistent effectiveness, while Nd:YAG and Er:YAG lasers exhibit favorable outcomes.

Conclusion: Overall, laser exposure to enamel surfaces before fixed orthodontic treatment is a valuable adjunct in preventive dentistry, helping reduce enamel side effects during orthodontic treatment.

Keywords: Lasers, Tooth Demineralization, White Spot lesion, Fixed Orthodontic Appliances, Dental Bonding

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1. Introduction

White spot lesions (WSLs), the "preliminary indication of a carious lesion on enamel observable without magnification," are prevalent iatrogenic consequences linked to orthodontic therapy.[1] WSLs generally manifest around the gingival borders of teeth, beneath the molar bands in regions where the cement has been weakened, on adhesive surfaces next to brackets and bands, and at the junction of bracket, adhesive, and conditioned enamel.[2] With a prevalence ranging from 2% to 96% depending on the detection method, WSLs can become visible as early as four weeks after starting orthodontic treatment. They may be fully apparent within the first six months.[3] The formation of these lesions is an aesthetic concern, making their prevention a significant challenge for clinicians.[4-5]

Orthodontic treatment, usually lasting 2 to 3 years, induces a rapid ecological shift in the microbial composition of dental biofilm due to the harbouring effect of plaque by the fixed orthodontic appliances in the mouth. Elevated levels of cariogenic bacteria, particularly Streptococcus mutans and Lactobacilli, lower plaque pH disturbs the cyclic balance between remineralisation and demineralisation of the enamel, leading to net mineral loss and the initiation of white spot lesions.(WSLs).[6-7]

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Preventive strategies for white spot lesions (WSLs) encompass the enhancement of patients' oral hygiene and the fortification of enamel resistance via fluoride products (including toothpaste, varnishes, gels, and mouth rinses), antimicrobials (such as chlorhexidine (CHX), fluoride-infused bonding agents, xylitol gum, casein derivatives, and additional methods utilising diverse mechanisms.[8-10] Given the limitations of current practices for preventing and treating WSLs, more effective and long-lasting therapeutic approaches have been proposed, including high-intensity lasers such as Argon, Nd, and CO2 lasers to irradiate enamel surfaces.[11-12] The proposed mechanisms of laser action involve reducing enamel permeability and solubility while promoting remineralization and microhardness, along with structural and chemical changes that make teeth more resistant to acid attacks.[13] Additionally, laser light can inactivate Streptococcus mutans, a key microbial contributor to caries development.[14] A significant advantage of using lasers over other WSL prevention methods is that they do not rely on patient compliance or require frequent reapplication by the clinician.[11-15] Stern and Sognnaes, in 1972, first recommended using ruby laser irradiation.[16] Although the US Food and Drug Administration (FDA) first authorized the CO2 laser for dental usage, other lasers have since been employed for preventative purposes.[8,14,17,21] Modifications to the enamel surface vary by laser type, notwithstanding their preventative efficacy. For instance, argon laser irradiation affects human enamel decalcification; argon and Nd: YAG lasers alter enamel's crystalline structure, enhancing its acid resistance. The Nd: YAG laser induces the melting and fusion of the prisms, thereby protecting the structure from acid exposure. The Er: YAG, Erbium-Doped Yttrium Aluminium Garnet and Er, Cr: YSGG- Erbium+ Chromium-doped Yttrium Scandium Gallium Garnet are suitable for the treatment of both soft and hard tissues.[20,22]

The clinical evidence regarding the efficacy of these lasers in preventing enamel demineralization in individuals undergoing fixed orthodontic treatment remains ambiguous. This systematic review aims to assess the in vivo efficacy of various lasers in reducing enamel demineralization orthodontic patients with fixed appliances and explore their potential in preventing WSLs.

2. Materials and Methods

Protocol and Registration: This systematic review has been registered with the International Prospective Registration of Systematic Reviews PROSPERO, CRD2020212233). The PRISMA-2020 guidelines for systematic reviews and meta-analyses were adhered to.[23]

2.1. Eligibility criteria

The PICO-S format was used to apply the following selection criteria for this review.

1. Participants: Patients of all ages (children, adolescents, and adults) and genders who had received orthodontic treatment with fixed appliances were included. Those who received other orthodontic treatments, like myofunctional or removable appliances, were excluded.
2. Intervention: Intervention group comprised the application of any laser beam with varied power settings during any phase of fixed orthodontic treatment.
3. Comparison: Laser-irradiated enamel (combined with any traditional prophylactic intervention) and control group (no intervention, placebo, or other standard preventive measures).
4. Outcomes: To assess the impact of lasers on the prevention and arrest of WSLs using methods such as visual examination, quantitative light-induced fluorescence, polarizing microscopy, and microhardness testing
5. Type of Studies: Included were randomized, nonrandomized, prospective, and retrospective investigations. Split-mouth studies were deemed eligible among randomised controlled trials (RCTs). Conference proceedings were omitted from cross-sectional clinical research lacking control groups, as well as from case series, case reports, editorial letters, correspondence, reviews, abstracts, author discussions, and interviews.

2.2. Information sources and search strategy

An extensive online database search in the Cochrane Library, PubMed Central, Science Direct, and Ovid® for material up to August 31, 2024 was performed. An additional search was conducted utilising Google Scholar, grey literature, and a manual review of cross-references from the included and relevant studies to guarantee that no significant new study was missed during the electronic search.

2.3. Search strategy

The literature search utilized diverse descriptors and Mesh (Medical Subject Headings) phrases, both independently and in conjunction through Boolean operators. ("OR" and "AND") using the terms- Orthodontics, Orthod’, Treatment, Therapy, Fixed, Appliances, Laser, Application, Irradiation, Enamel, Dissolution, Decalcification, Hardness, Caries, lesion, White Spot lesion, Prevention, and Resistance). Supplementary Table I.

Table 1: The characteristics of included studies

S. No.	Author and year of publication	Study type	Country	Number of Teeth (n)	Sample size (L= laser-treated teeth, C= Control teeth	Treatment comparison	Type of laser used	Specifications of laser beam used	Irradiation protocol	Follow up
1.	**Blankenau et al. (1999)[20]**	CS	USA	8	L=4 C=4	L= laser treated group. C= Untreated group.	Argon laser (HGM Model 5)	Energy density- 12 J/cm2 Power- 250mW Time- 10 sec Beam Diameter- 5mm	The experimental teeth were exposed to argon laser radiation prior to tooth extraction. Both the experimental and control teeth had modified orthodontic bands cemented. to them.5 weeks after band placement, teeth were extracted and studied.	5 weeks.
2.	**Anderson et al. (2002)[25]**	RCT	USA	36	C=9 L=9 PL=9 PEL=9	C=untreated group. L=laser only PL= pumice-laser group PEL= pumice-etch-laser group.	Argon laser (AccuCure 3000, Laser Med, Salt Lake City, Utah))	Beam diameter-5mm Power-325mW Time-60sec Energy density-100J/cm2 Distance from tooth surface 3 mm.	The experimental teeth were exposed to argon laser radiation prior to tooth extraction. Both the experimental and control teeth had modified orthodontic bands cemented.Teeth were extracted five weeks after the band was put on, immediately submerged in ten ml of distilled water, disinfected, and kept at 4˚C until sectioning.	5 weeks
3.	**Elaut (2004)[26]**	RCT	Europe	212	C=106 L=106	C= control group treated with conventional light curing. L= Laser treated group	Argon laser [Flexilas Argon Laser, A.R.C. Laser GmbH, Eckental, Germany; strong emission lines: 488 and 514.5 nm]	Beam diameter-5mm Power-250mW Time- 5sec each from gingival and incisal Energy density-12J/cm2 Distance from tooth surface 2mm	The experimental teeth are bonded using an argon laser, while the control teeth are covered with thermoformed aluminum or plastic foil after the brackets on the control teeth have been cured using conventional visible light curing.	14 months.

4.	**Hicks et al.(2004)[27]**	CS	USA	14	NM	L= laser treated group. C= Untreated group. FL=Fluoride+ laser group	Argon laser (ARGO-MOD, Premier Laser Systems)	Density – 12J/cm2 Power-250mW Time-10sec	The experimental teeth were exposed to argon laser radiation prior to tooth extraction. Both the experimental and control teeth had modified orthodontic bands glued to them.Teeth were extracted 5 weeks after the band was placed and kept in 10% buffered formalin until sectioning.	5 weeks
5.	**Rechmann et al.(2011)[28]**	RCT	USA	24	L=24 C=24	L = laser-treated group. C Untreated group.	CO2 laser. (Pulse System, Inc. (PSI) (Model #LPS-500, Los Alamos, New Mexico)	Wave length-9.6µm Pulse duration-20µs Pulse repetition rate- 20Hz Beam diameter-1100µm 20 laser pulses Fluence per pulse-4.1 ± 0.3 J/cm2	A CO2 laser was employed on one side of the cervical enamel surface near an imaginary line perpendicular to the bracket slot. In contrast, the other side served as a control, after brackets were bonded on the buccal surface of the extracted bicuspids. There was only one laser application during the study period.	Group1= 4 weeks Group2= 12 weeks
6.	**Miresmaeili et al.(2014)[29]**	RCT	Iran	32	L=16 C=16	L = laser-treated group. C= Untreated group	CO2 laser (DEKA Laser Technologies, Florence, Italy)	Wavelength-10.6µm Pulse duration-3 sec Repetition rate-5Hz Beam diameter-0.2mm Power-0.7W	Both the experimental and control groups had brackets attached to them. To increase the accumulation of plaque, the T loop was activated. After two months, the teeth were extracted and soaked in 10% formalin for 48 hours. They were then allowed to sit at room temperature in distilled water until they were sectioned. Placing the band	2 months.
7.	**Kaur et al (2017)[30]**	RCT	India	100	G0 =20 G1 =20 G2 =20 G3 =20 G4 =20	G0 = Control group without any bonding and surface treatment. G1 =CO2 laser group G2 = Er, Cr: YSGG laser G3 = 5% NaF fluoride varnish. G4 = bonded premolar with no surface treatment.	CO2 (FUTURA R2 CO2 Fractional laser, Inc. USA) Er, Cr: YSGG (BIOLASE Waterlase® YSGG, BIOLASE®	**CO2 laser** Wavelength-10.6 µm Power -1 W Beam diameter- 1 mm Frequency 20 HZ Time-12 s **Er, Cr: YSGG laser** Wavelength-2.78 µm Power- 0.75 W Beam diameter- 1 mm Frequency -20 HZ Time-20 s	An elastomeric ligature was used to promote plaque accumulation to engage the T loop. Teeth were extracted after two months, soaked in 10% formalin for 48 hours, and then sectioned in distilled water at room temperature.	2 months

							Technology, Inc. USA).	Distance from tooth surface 1 mm.		
8.	**Raghis et al (2018)[31]**	RCT	Syria	510	L=255 C=255	L = laser-treated group. C= nontherapeutic light (Placebo)	CO2 laser (CL-20 Enterprise Standard: YZB/State 1317-2007)	Wavelength: 10.6 µm Pulse duration:3 s Power: 0.7 Watts Irradiation time-10 mins.	Following bracket bonding, a CO2 laser was applied around the orthodontic brackets in the experimental quadrants. A non-therapeutic light was applied to the control quadrants. Throughout the study period, the CO2 laser was only used once.	1 month (T2), 2 months (T3) and 6 months (T4).
9.	**Mahmoudzadeh et al (2019)[7]**	RCT	Iran	554	L= 278 teeth C= 276 teeth	L= laser treated group. C=Sham light (Placebo).	CO2 laser	Wavelength -10.6 µm Power- 0.4 MW Frequency - 5 Hz, Diameter- 0.2 mm Pulse time- 9 s Distance from tooth surface 5mm	Maxillary anterior teeth in the laser group were subjected to a CO2 laser after the brackets had been bonded to the tooth surface. At the same time, the control group's samples were treated to sham light.	1 week after the brackets are bonded. 6 months
10.	**Harazaki et al. (2001)[33]**	RCT	Japan	120	L=10 C=10	L Laser +APF solution treated group. C = Untreated group.	Nd-YAG (CONTACT LASE, S.L.T. Japan Co., Ltd.)	Pulse width- 0.3ms Pulse energy- 0.75J Power- 2x10W Repeated- 20pps Time- 5sec Irradiation density- 40J/cm	After brushing and water rinsing, the teeth were dried. Laser irradiation and applying a black liquid agent were carried out in the laser group. No therapy was administered to the control group. The incisors were the center of the photographs. The photos were taken again with the same specifications a year later.	1 year
11.	**Suetenkov et al.(2015)[14]**	RCT	Russia	Not reported	L=30 C=30	L= 2 laser devices+ traditional preventive measures C traditional preventive measures	Optodon laser (VEND, Russia) + Fotosan (CMS Dental, Denmark)	**Optodon laser** Wavelength- 0.98-0.85µm Power-0.5-1W Pulse repetitive rate- 2000Hz 2mins for each segment.	The exposure area includes two segments (upper and lower teeth alignment).Four times per year 3 months apart was recommended. Fotosan was used in 4 segments (2 upper and two lower) in combination with toluidine blue as a photosensitizer.	1 and ½ years
								Fotosan Wavelength- 630 nm Power- 0.4W 10s for each segment.		

Table 2: Results of the included studies

S No	Author and year of publication	Type of laser	Method of assessment	Primary outcome	Results	Relevant Conclusion
1.	**Blankenau et al. (1999)[20]**	Argon laser	Polarised light microscopy	Depth of the WSL in mm.	23.4% to 33% (average 29.1%) lesion depth reduction in the laser group compared to the control group. Statistically substantial difference between groups.	In clinical settings, demineralization was considerably decreased by low-power argon laser irradiation. .
2.	**Anderson et al. (2002)[25]**				**Reduction of lesion depths compared with the control**	
		Argon laser	Polarized light microscopy	Lesion depth (µm) Lesion area (µm2).	L=91.6% PL=58.9% PEL= 89.1%	During orthodontic therapy, argon laser irradiation effectively reduces enamel decalcification. Pumicing and etching did not reduce the laser's effect on the enamel's solubility.
					Reduction of lesion area compared with the control	
					L=94.6% **PL**- 46.0% **PEL**-92.2%	
					Statistically significant difference in lesion depth and area for the four groups. Statistically significant difference.	
					Between PEL and C and L and C groups. There is no statistically significant difference between the PL and C groups, maxillary and mandibular teeth, and between the right and left sides.	
3.	**Elaut (2004)[26]**	Argon laser	Photography	Enamel demineralization, Plaque accumulation Bond failure rate.	**Bond failure:** Overall failure rate in brackets (371) bonded with argon laser is 2.4 %(9), and those bonded with conventional light (371) is 5.7 %(21), with a significant difference between them.	Regarding chairside time and clinical bond strength, argon laser curing is more effective than traditional light curing. The incidence of decalcification and plaque buildup was similar for both curing techniques.
					Enamel demineralization: 54.7% of the teeth (58/106) bonded with conventional curing light and 58.5% (62/106) bonded with argon light exhibited increased demineralization at the end of the study.	
					Plaque accumulation: Teeth irradiated by argon laser and conventional visible light had the mean plaque scores of 2.39(SD=0.81) and 2.34(SD=0.86).	

					No statistically significant differences were found among argon and conventional laser irradiated groups regarding enamel demineralization and plaque accumulation.	
4.	**Hicks et al.(2004)[27]**	Argon laser	Polarized light microscopy	Lesion depth(µm)	Mean reduction is 44% in the L group and 62% in the FL group compared to the C group. Mean reduction of 32% in the FL group compared to the L group.	Clinically, a single low fluence argon laser irradiation dramatically reduced the development of natural caries in vivo. Combined fluoride and argon laser irradiation offered an even higher level of caries resistance than argon laser alone.
5.	**Rechmann et al.(2011)[28]**	CO2 laser	Relative mineral loss, ΔZ, was determined through cross-sectional micro hardness testing.	Relative mineral Loss ΔZ (vol% × µm)	**4 weeks of arm** The laser treatment produced a 46% demineralization inhibition compared to the non-laser-treated control group.	Human enamel tooth caries can be successfully prevented by specific short-pulsed 9.6µm CO2-laser irradiation.
					12 weeks of arm The laser treatment produced a marked 87% demineralization inhibition.	
6.	**Miresmaeili et al.(2014)[29]**	CO2 laser	Vickers microhardness testing machine (KB Pruftechnik, Hochdorf-Assenheim, € Germany)	Enamel surface micro hardness (VHN).	Enamel surface micro hardness was significantly greater in the laser-treated group (301.81±94.29 VHN) compared with the control group (183.9±72.08VHN).	At a wavelength of 10.6 µm, CO2 laser irradiation may increase surface microhardness and decrease enamel demineralization.
7.	**Kaur et al (2017)[30]**	CO2 laser And, er, Cr: YSGG used in separate groups	Scanning electron microscope Vickers microhardness testing machine	Enamel surface changes	**Surface changes of the enamel** G0 - Circular enamel rods filled with interrod material form a keyhole. G1- uniform enamel surface with small cracks and fractures. GII - Melting enamel rods creates a glossy surface with well-cooled rods. GI - minor eroded areas GIV - eroded enamel.	The Er, Cr successfully increased the enamel surface microhardness: YSGG laser and the CO2 laser; however, fluoride varnish surface treatment had no noticeable effect. SEM analysis revealed that CO2 laser surface treatment produced fissures and cracks that might serve as plaque-retentive zones. Er, Cr: YSGG laser enhanced the enamel surface's resistance to demineralization with optimum microhardness.
					Mean microhardness(VHN) Groups I, II, III, IV, and 0 have significantly different mean micro hardness (VHN).	
8.	**Raghis et al (2018)[31]**			**Primary outcome:**	**Primary outcome:**	
		CO2 laser	DIAGNO dent. Clinical and photographic examinations.	To assess the presence or absence of at least one new DL.	DLs had no significant difference between groups at T1 and T2 but rose at T3 and T4.	DL development is inhibited during orthodontic treatment when the enamel surface is laser-irradiated with a CO2 laser (at a wavelength of 10.6µm).
				Secondary outcome:	**Secondary outcome**:	

				1. Digital photographic image evaluation for the presence or absence of DLs. 2. Geiger index 3. DL area using the AutoCAD 2014 program. 4. DIAGNOdent score.	1. DL decreases significantly at T3 and T4 after digital picture evaluation. 2. At T2, the Geiger index showed no significant differences between control and experimental groups, but at T3 and T4, it did. 3. First and second AutoCAD DL area readings are highly correlated. Hotelling T2 test indicated no significant variations in DL area between groups at T2. 4. DIAGNOdent rose at T2 and declined marginally at T3&T4. 5. No severe enamel, gingiva, or pulp tissue damage was identified.	.
9.	**Mahmoudzadeh et al (2019)**[7]	CO_2 laser	Photography	Incidence, extent, and severity of WSLs.	The control group had a substantial difference in WSL incidence between baseline and 6 months post-irradiation. No significant difference was found in the laser group. After CO_2 laser irradiation, incisal, mesial, and distal lesions decreased dramatically, while gingival lesions did not. The mesial and incisal lesions were much less severe than the gingival and distal ones.	It appeared that the CO_2 laser irradiation successfully reduced the occurrence of WSLs. Furthermore, the effectiveness varies based on the surface area. .
10.	**Harazaki et al. (2001)**[33]	Nd-YAG	Photography	Surface area.	There was a mean increase of 141% in the WSL area in the laser group and 287% in the control group. 2 out of 10 cases showed a decrease in WSL area. The difference between the two groups was statistically significant.	Laser treatment produced a noticeable difference from the control when applied in a clinical setting. The Nd-YAG laser effectively inhibited dental caries development.
11.	**Suetenkov et al.(2015)**[14]	Both Optodon Laser And Fotosan together	**Methods for Caries Detection:** 1. Method of drying. 2. Method of reflection. 3. Periodontal probing method. 4. Vital coloring. 5. X-ray tests. **Determination of hygiene status**: OHI-S **Determination of marginal periodontium condition:** Papillary marginal attached index modified by Parma (1960).	Decayed, missing, filled teeth (DMFT) index; decayed, missing, filled tooth surfaces (DMFS) index; oral hygiene status (OHI-S); papillary marginal attached (PMA) Index.	The laser group showed a significant decrease in the growth of dental caries intensity and surface caries intensity (ΔDMFT, ΔDMFS) and gingivitis compared with the control group.	Adolescents with fixed orthodontic appliances have shown the greatest success in preventing caries and gingivitis when low-intensity laser irradiation (OPTODAN and FotoSan) is combined with conventional preventative methods.

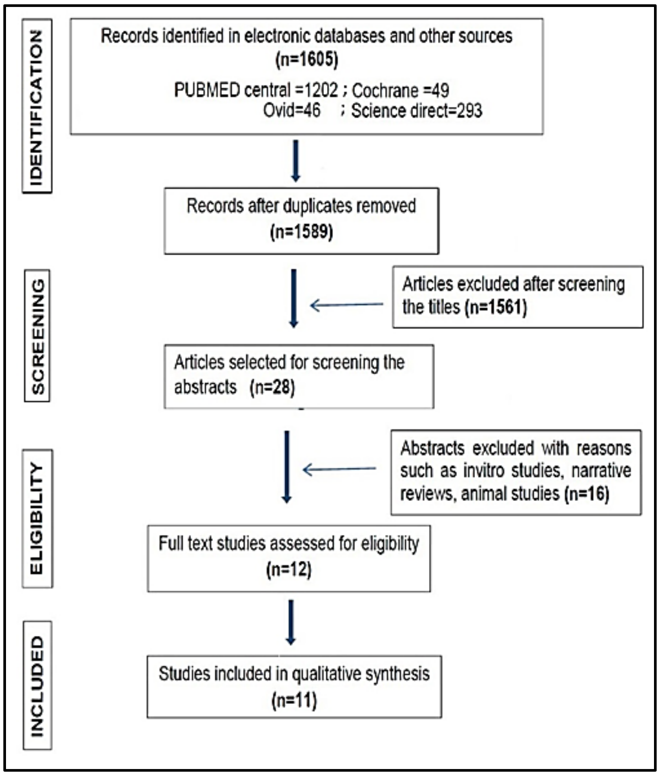

Figure 1: The preferred reporting items for systematic reviews and meta-analysis (PRISMA) flow diagram of the study selection.

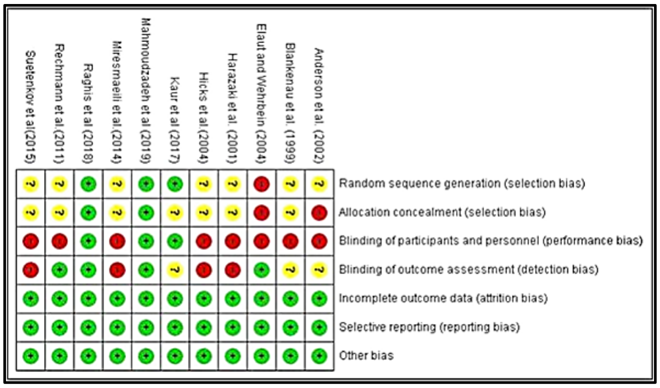

Figure 2: Risk of bias summary: Review the authors' judgments regarding each risk of bias item for each included study.

2.4. Study selection

Two authors (GSS, HK) independently reviewed the titles and abstracts of records retrieved from the literature search that met the eligibility criteria. We rejected papers with unsuitable names and ambiguous, absent, incomplete, or redundant data. Discrepancies in opinion were resolved through discourse, and where the two researchers are discordant, a third reviewer was consulted (PM). The details of rejected studies and their reasons for exclusion are provided in the Supplementary Section.**(Table 2)**

2.5. Data items and collection

Two authors (GSS, HK) extracted data from a list of studies included for review. The characteristics of included studies were organized into the following study characteristics: authors and publication details, type of study, sample characteristics, treatment comparison, type of laser used, specifications of a laser beam, irradiation protocol, and follow up—**Table 1**.

The primary outcome, evaluation method, and significant differences between the control and treated groups were also documented **Table 2**.

2.6. Quality assessment and risk of bias in individual studies

The potential for bias in studies included was separately evaluated by the same two authors (LI, GSS) employing "The Cochrane Collaboration" methodology for evaluation of randomised controlled trials.[24] [Figure 2].

2.7. Effect measures and synthesis methods

The included studies exhibited significant variation in the types of lasers and outcome measures, including various laser properties such as power, wavelength, frequency, and energy density, as well as irradiation protocols, follow-up durations, results, and measuring methodologies. Therefore, the review was restricted to only qualitative synthesis of outcome measures.

3. Results

We retrieved 1,605 articles through literature and hand searches, which were reduced to 1,589 after removing duplicates. After screening article titles, 1,561 irrelevant titles were excluded—Supplementary **Table 2**.

Twenty-eight articles were selected for abstract screening, of which 16 were excluded for various reasons, including in-vitro studies (n=10), narrative reviews (n=1), animal studies (n=3), unavailability of the full text (n=1), and patients with a removable appliance (n=1). Twelve studies were assessed for full-text eligibility. One article was omitted in the full-text phase as it was a duplicate publication.

*3.1. Study characteristics (**Table 1**)*

Among the final 11 articles, 9 were randomized clinical trials, while the remaining two were clinical pilot studies. Pooling participants from 9 out of 11 studies, a total of 304 participants and 1610 teeth were assessed. Four studies utilized argon laser;[20,25,27] in another four, CO2 was employed;[7,28-31] A study employed both CO2 and erbium, chromium: yttrium scandium gallium garnet lasers (Er, Cr: YSGG) in distinct groups.[30] another study adopted Neodymium-doped yttrium Aluminium garnet (Nd-YAG)[32] and diode laser was used in one study.[14]

3.2. Reporting bias of included studies

The methodological quality scores for risk of bias are presented in Figure 2. Two studies were free from all bias types and rated as fair quality.[7,31] The most significant issue was performance bias due to inadequate blinding of participants and performance, observed in all but three studies.[7,30-31]All the studies exhibited low risk concerning attrition, reporting, and other bias. Selection bias related to allocation concealment indicated a low risk in two studies.[7,31] The majority of the studies displayed an unclear risk for random sequence generation (selection bias)[14,20,25,27-29,32] except high riskobserved for one study,[26] and three studies exhibiting low risk.[7,30-31]

*3.3. Summary of measured and approach synthesis. (**Table 2**)*

1. **Argon Laser:** Four studies researched the impact of argon lasers on the demineralisation. Enamel.[20,25-27]Three studies showed a significant reduction in lesion depth, ranging from 29.1% to 91.4%.[20,25-26] Fluoride application before laser treatment further enhanced the reduction by approximately 32% compared to laser treatment alone.[27] Overall, argon lasers effectively reduce enamel demineralization and lesion depth, especially when combined with fluoride.
2. **CO2 laser:** In the four studies examining CO_2 laser treatment, Mahmoudzadeh et al. found that new white spot lesions (WSLs) emerged in 8.7% of cases within the control group over 6 months, whereas the laser-treated group exhibited enhancement in baseline lesions and a reduction in new lesions, demonstrating a statistically significant disparity in WSL incidence between the two groups after 6 months.[7] Rechmann et al. reported a 46% reduction in demineralization around orthodontic brackets at 4 weeks and an 87% reduction at 12 weeks compared to controls.[28] Miresmaeili et al. found that enamel treated with laser exhibited higher surface microhardness (301.81 ± 94.29 VHN) compared to the control group (183.9 ± 72.08 VHN), representing a 64% improvement ($P < 0.001$).[29] Raghis et al. observed no significant difference in demineralized lesions (DLs) between groups at 1 month. Still, at 2 and 6 months, DLs increased significantly in the control group by 6.9% and 27.1%, respectively, compared to the laser-treated group ($P < 0.0001$).[31] Overall, these studies highlight the effectiveness of CO_2 lasers in minimizing demineralization, enhancing enamel hardness, and reducing the incidence of demineralised lesions over time.
3. **Diode lasers:** Suetenkov et al. reported significant reductions in caries and surface caries intensity when using the optodon laser.[14,20,25,27] The experimental group's caries intensity and surface caries intensity values were 1.05 ± 0.14 and 1.37 ± 0.13, respectively, while the control group's values were 2.77 ± 0.56 and 2.66 ± 0.30 ($P < 0.001$). The efficiency of the optodon laser in preventing dental cavities was demonstrated by the 62% reduction in caries intensity and the 48% reduction in surface caries intensity when compared to the control group.
4. **Nd: YAG laser:** According to Harazaki et al., after a year, the area of white spot lesions increased by an average of 1.41 times in the laser-irradiated group and 2.87 times in the controls, with a notable difference between the groups.[32]
5. **CO2 laser, Er, Cr: YSGG laser, and Fluoride:** In comparison to a control group, Kaur et al. assessed the combined effects of lasers such as Er, Cr: YSGG, CO_2 and 5% neutral sodium fluoride varnish on the microhardness of the enamel surface.[30] While fluoride varnish had no discernible effect on enamel microhardness, the CO_2 laser and the Er, Cr: YSGG laser successfully raised the microhardness of the surface of enamel by 52% and 28%, respectively. According to SEM examination, the CO_2 laser therapy caused fissures and breaks on the enamel surface, which may be places where plaque can accumulate. While the Er, Cr: YSGG laser treatment positively affected the enamel surface, improving its resistance to demineralisation and reaching ideal microhardness, fluoride varnish displayed minor areas of degradation.

4. Discussion

The enamel caries is preceded by a white spot lesion. The spread and severity of the white spot lesions is significantly higher among patients wearing fixed appliances, resulting in esthetically undesirable results.[4,11,33] Because it is essential to prevent the aesthetics of the smile from being affected, one of the biggest issues facing orthodontic clinicians is preventing demineralisation during treatment.

Literature has employed a variety of techniques to stop the enamel from demineralizing. Increasing enamel resistance through laser treatment is one such method. Argon, CO2, Er:Cr: YSGG, Nd: YAG, Er: YAG, and diode lasers are among the several lasers employed for this purpose.[7,14,20,25-32]

4.1. Study selection and characteristics

The in-vitro effectiveness of lasers in the prevention of white spot lesions has been widely studied, with CO_2 and Argon lasers being the most commonly used.[20,25-27] Studies have identified Argon, CO_2, Nd: YAG, and Er: YAG lasers as the principal types used in preventive dentistry.[34-36] Although lasers have demonstrated the ability to strengthen enamel's resilience to demineralisation during orthodontic treatment, they currently have little clinical use. The efficiency of laser irradiation in halting demineralisation of enamel during fixed orthodontic treatment was investigated in this systematic review.

In all included studies, lasers were applied once at the start of treatment, except for Suetenkov et al., where laser application was repeated quarterly.[14] Outcomes in most studies were assessed through clinical and photographic evaluations, with one study using DIAGNOdent for detecting demineralized lesions.[31] Quantitative light-induced fluorescence (QLF) offers faster and more precise results than traditional methods such as transverse microradiography, polarized light, and microhardness techniques, making it a promising tool for clinical evaluations of incipient caries lesions.[37-39]

5. Summary of Evidence

According to this review, lasers can effectively lessen the negative effects of fixed orthodontic treatment on tooth enamel, especially when halting the growth of white spot lesions (WSLs). The incidence of WSLs, lesion depth, surface area, extent, severity of lesions, enamel microhardness, surface alterations, and mineral loss were among the key outcomes of the 11 included studies, nine of which were only concerned with laser therapy of the enamel surface.[7,20,26-31] Apart from primary outcomes, two studies evaluated secondary outcomes, such as dental caries intensity, periodontal effects, and bond failure rate.[14,21]

5.1. Primary outcomes

5.1.1. White spot lesions

A significant decrease in the incidence of WSLs was observed in both studies that used a CO_2 laser.[7,31] Despite this, no noticeable difference was found between the control and laser-treated groups when an argon laser was applied.[25]

Using Argon lasers, three clinical investigations assessed WSL depth.[20,25,27] According to these investigations, the laser-treated groups' lesion depth was statistically significantly less than that of the control groups. With a 5 mm beam diameter, 325 mw power, 100 J/cm² energy density, and a 3 mm distance from the tooth, an Argon laser produced the greatest reduction in lesion depth (94.1%). Flaitz CM et al. discovered that there is a synergistic effect when acidulated phosphate fluoride is combined with the irradiation of Argon laser, resulting in considerably decreased lesion depth compared to control lesions.[40] Furthermore, Adel said the least amount of lesion depth was achieved by inhibiting enamel demineralisation using the combination of Er, Cr: YSGG Laser and CPP-ACP.[41]

Three clinical studies evaluated the area of White Spot Lesions (WSLs), using Argon Laser, Nd: YAG, and CO_2 laser.[25,31-32] The CO_2 and Argon lasers showed a statistically significant decrease in lesion area. The lesion area, however, grew 1.41 times in the Nd: YAG laser group as opposed to 2.87 times in the control group. These results align with a study by Tavares et al. that also demonstrated the Argon laser's greater efficacy over the Nd laser by proving that its in vitro use produced the smallest demineralisation area in enamel.YAG laser for preventing dental cavities.[21]

6. Enamel surface changes

Two studies evaluated the effects of lasers on enamel microhardness.[29-30] Miresmaeili et al. found a significant difference in microhardness values, with the CO_2 laser group exhibiting higher enamel microhardness than the control group.[29] Similarly, Kaur et al. found that the enamel microhardness increased significantly when comparing the Er, Cr: YSGG and CO_2 laser groups to the control group.[30] Similar outcomes have also been noted in the past. Compared to untreated enamel, Westerman et al. found that irraration with an argon laser is associated with increase in red that CO_2 laser exposure enhanced the microhardness of the enamel surrounding orthodontic brackets with or without fluoride application.[42] Korytnicki et al. showed that Nd: YAG laser irradiation enhanced enamel hardness and reduced acid vulnerability.[43]Poosti et al. showed that applying fluoride after fractional CO_2 laser irradiation greatly enhanced enamel microhardness.[44]

SEM evaluation showed that in a group irradiated with Er, Cr: YSGG laser, a favourable positive surface enamel alteration was found, which increased the ability of enamel to resist demineralization.[30] Esteves-Oliveira et al. further demonstrated that the irradiated surfaces in every group resembled the controls not exposed to radiation.[18]

Compared to the control group, CO_2 laser treatment prevented mineral loss by 46% after four weeks and 87% after twelve weeks.[28] According to Paulos et al., the CO_2 laser significantly decreased mineral loss.[15] According to Rodrigues et al., fluoride treatment significantly reduced enamel mineral loss caused by CO_2 laser therapy.[19] Fekrazad and Ebrahimpou found that combining Er, Cr: YSGG laser with fluoride reduced enamel solubility more than the laser alone.[45] After fluoride treatment, Liu et al. showed that a low-energy Er: YAG laser reduced mineral loss by transforming enamel hydroxyapatite into fluoridated hydroxyapatite.[46]

6.1. Secondary outcomes

1. **Dental and surface caries intensity:** The low-intensity "OPTODAN" laser effectively prevented caries.[14] Similarly, Brandão et al. discovered that in children at high caries risk, CO_2 laser treatment, with or without acidulated fluoride, successfully prevented cavities on the occlusal surfaces of partially erupted permanent first molars.[47]
2. **Periodontal outcomes:** The argon laser and control groups did not significantly vary in terms of plaque

accumulation.[25] Abellán R et al. observed similar findings, indicating a small deterioration of periodontal health in the diode laser and control groups.[48] Among the studies we included, the laser group showed a substantial decrease in gingivitis and inflammation of marginal periodontal tissue when compared to the control group.[14] The study by Khatri KS et al. showed that additional treatment with Gallium-Aluminium-Arsenide (Ga-Al-As) diode laser reduced the periodontal indices, as evaluated by the plaque index, bleeding on probing, the gingival index, and pocket depth.[49] Ren et al. demonstrated that the Ga-Al-As laser-treated side displayed reduced plaque buildup and gingival irritation compared to the placebo side throughout the initial month.[50]

3. **Bond Failure Rate:** Only one study reported no significant difference in plaque accumulation between the argon laser and control groups.[26]

This review is an update on the previous systematic review by Raghis et al.[51] With three more articles, all three use a CO2 laser.[7,31-32] The studies included in both these systematic reviews are short-term follow-up studies, except one study by Suetenkov et al., which assessed the outcomes after the entire orthodontic treatment.[14] Our evaluation of the included studies' quality showed that, except for two, their shortcomings were primarily in the poor description of the randomisation process, which left the included studies with an unclear or high risk of bias.[7,31] Additional limitations include the small sample numbers in these research, brief follow-up durations, and the heterogeneity among the studies.. Furthermore, future clinical trials should adopt quantitative methods like QLF to enhance diagnostic accuracy, which reliably evaluates mineral changes in incipient enamel lesions. Notwithstanding the aforementioned constraints, we maintain that this evaluation will furnish the most appropriate evidence regarding the usefulness of lasers in preventing enamel demineralisation in individuals receiving fixed orthodontic treatment.

7. Conclusion

Laser treatment of enamel surfaces, particularly CO_2, Er: YAG, and Nd: YAG lasers, has shown significant effectiveness in preventing WSLs, enamel demineralization, reducing caries, and improving enamel microhardness. Combining laser treatments with fluoride enhances their protective effects, particularly in high-risk populations, such as children with partially erupted molars. While CO_2 lasers have consistently reduced mineral loss and prevented caries, other lasers like Nd: YAG and Er: YAG also offer promising results. Overall, laser therapy to enamel surfaces, before fixed orthodontic treatment, presents a valuable adjunct in preventive dentistry, especially during orthodontic treatment, to mitigate the side effects on enamel. Further in-vivo and clinical experiments are necessary to compare various lasers to determine the most effective laser, the appropriate laser parameters, the need for adjunctive preventive measures such as topical fluoride along with the lasers.

8. Source of Funding

None.

9. Conflict of Interest

None.

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