IJL, Issue 1, Vol. 24, 2025 **Research Article**
https://doi.org/10.31900/ijl.v24i1.514

IRAQI JOURNAL OF LASER

In vitro investigation: the impact of MI varnish and fractional CO_2 laser on demineralized enamel surfaces

Ayat Majid Salih[1,*], Aseel Jasim Ali[2], And Soudad Salman Ahmed[3]

[1] *Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq*
[2] *Department of Oral Medicine, College of Dentistry, Al-Mustafa University College, Baghdad, Iraq*
[3] *Department of Physics, Faculty of Science, University of Baghdad, Baghdad, Iraq*
* *Email address of the Corresponding Author: ayatalsaraj@gmail.com*

Article history: Received: 15 Dec. 2024; Revised: 5 Apr. 2025; Accepted: 22 May 2025; Published online: 15 Jun. 2025.

Abstract: To assess the therapeutic efficacy of fractional CO_2 laser and MI varnish alone and their combined effects in two cases (CO_2 Laser before and after the application of MI varnish). Method: 60 enamel samples were prepared, and then the samples were passed through the pH cycling process to induce a demineralized enamel surface. The samples were categorized into five groups: control, CO_2 laser, MI varnish, CO_2 laser with MI varnish, and MI varnish with CO_2 laser. Surface alterations were evaluated using the Vickers microhardness assessment, surface roughness, and the Scanning Electron Microscope (SEM) combined with the Energy-Dispersive X-ray Spectroscopy (SEM-EDX).Results: All of the microhardness results were diminished after the demineralization process, and then subsequently, the different treatments enhanced the demineralized enamel surface with no notable distinction among the treatment groups. The surface roughness data showed improved surface roughness in the CO_2 laser-containing groups. The surface morphology and mineral weight were enhanced after the treatments.
All treatment groups were effective in enhancing the microhardness, roughness, and surface morphology in comparison to the control group, preferring the simultaneous application of CO_2 laser and MI varnish in both instances (similar results).

Keywords: MI varnish, fractional CO_2 laser, hardness, roughness, combined use.

1. Introduction

Enamel serves as the protective layer of the tooth. It is a rigid, slender, opaque material that envelops and safeguards the dentin. Enamel comprises 96% inorganic material substances, 4% organic compounds, and water. So, it is the most mineral-rich tissue in the human body [1]. Tooth decay, or dental caries, is caused by germs such as Streptococcus mutans in dental plaque, which generate acids that erode the teeth, resulting in demineralization. This bacterium is prevalent in the oral cavity and leads to dental caries [2].
Hypomineralized enamel exhibits diminished mineral content, a disordered structure, expanded prism sheaths, and decreased calcium levels while possessing elevated carbon and protein concentrations compared to healthy dental enamel [3]. This produces a surface that is more porous and less resilient than healthy teeth [3,4]. The probability of developing dental caries is increased [5]. An imbalance between

demineralization and remineralization may result in mineral loss from the outer surface, leading to carious lesions. If remineralization is more effective, these lesions can be stopped and restored(6). The objective of remineralization procedures is to augment the mineral composition of under-mineralized tooth tissues, hence improving their physical qualities and increasing their resistance to decay(7). This process involves reintroducing calcium phosphate ions into the lesion, where they solidify. The concentration must be higher than that in the lesion to ensure the calcium phosphate ions diffuse into the enamel through micropores. However, the concentration should not be so high that it causes surface precipitation, which can block tubules and hinder ion entry into the white spot lesions(8).

The loss of hard tissue in teeth results from two main processes: the degradation of apatite crystals in the enamel and the movement of calcium, phosphate, and hydrogen ions. Demineralization starts with subsurface lesions that can develop into visible clinical lesions if it continues(9). In managing tooth decay, it is important to detect early lesions and employ remineralizing chemicals to avert more decay and cease the demineralization process prior to cavity formation(10). It's been confirmed that high-calcium mineralizing agents can reverse white spot lesions and prevent them from progressing to cavities(11).

Recently, this noninvasive technique was used to maintain the preservation of dental integrity against carious decay and to avoid the occurrence of incipient lesions. Fluoride use is an efficient method to prevent enamel demineralization and facilitate remineralization, even at minimal fluoride doses(12). MI varnish is a commercial formulation consisting of casein phosphopeptide, amorphous calcium phosphate, and fluoride, which possesses mineralizing properties that replenish lost ions in demineralized enamel(13). The effect of varnish on enamel exceeds that of alternative topical fluoride treatments such as toothpaste, gels, and mouthwashes(14). Varnishes are more acceptable, do not require patient cooperation, and cause less discomfort to the patients(15). In a study conducted by Cochran et al.(16), the efficacy of casein phosphopeptide stabilized amorphous calcium phosphate (CPP-ACP) and amorphous calcium fluoride phosphate (CPP-ACFP) in the remineralization of enamel subsurface lesions was evaluated. The CPP sequesters free calcium, fluoride, and phosphate ions and hinders the precipitation of mineral ions at neutral pH. Nonetheless, this binding diminishes when the pH is decreased to 5.5 or below, facilitating the release of mineral ions.

When fluoride is added to HAP, it becomes fluorapatite (FAP), with lower solubility and increased acid resistance(17). The introduction of casein phosphopeptide-amorphous calcium phosphate paste (CPP-ACP) has proven to be a useful method for augmenting enamel resistance to caries; CPP consists of A congregation of phosphoryl residues stabilizes ACP nanoclusters in a metastable solution. It is an adhesive protein that associates with phosphate and calcium ions, stabilizing them in an amorphous state(18).

The CO_2 laser with a 10,6µm wavelength is highly recommended as its penetration depth is tenfold deeper without compromising the pulp tissue or elevating its temperature(19). The absorption of this range occurs at the carbonate, phosphate, and hydroxyl groups that are in hydroxyapatite crystals(20). The absorption of laser light by minerals induces structural and chemical alterations in enamel crystals, evidenced by the thermal disintegration of carbonated hydroxyapatite, which diminishes dissolution and improves resistance to acid assaults(21). The surface alterations penetrate to a depth of 58 µm, thereby diminishing demineralization by up to 98% in the enamel surface(22). If the laser is used improperly with a high dose, this will lead to enamel surface carking and irregularities, which will decrease enamel hardness and increase brittleness(23). When utilizing a laser for caries prevention, it is essential to keep the laser energy below the ablative threshold to effectuate chemical alterations in the enamel surface without inflicting morphological damage(24).

Esteves-Oliveira et al. observed diminished mineral loss and the re-hardening of softened enamel in samples solely treated with CO_2 laser; however, the combination of fluoride and subsequent CO_2 laser irradiation significantly prevented alterations in surface microhardness(25). The enhancement in hardness may be attributed to crystal development associated with temperature fluctuations, resulting in larger crystals and a reduction in crystallographic defects(26). Ramalho et al. discovered that both CO_2 laser irradiation alone and the combination fluoride-laser therapy resulted in reduced mineral loss compared to the fluoride group across all storage durations(27). Laser and fluoride have synergistic effects, improving enamel acid resistance attributable to the elimination of organic matrix, augmented fluoride absorption, and expanded surface area for ion adhesion(26). Irradiating CO_2 laser with fluoride application may result in the development of fluorohydroxyapatite and calcium fluoride (CaF_2) on the enamel surface. These compositions act as a fluoride reservoir during enamel demineralization and are employed in the subsequent remineralization process(20).

This study assessed and contrasted the efficacy of fractional CO_2 laser, MI varnish, and combined methods in improving the surface characteristics of demineralized enamel. The null hypothesis examined was that none of these methods can improve the surface characteristics, microhardness, and roughness of the demineralized enamel surface.

2. Material and Method

Thirty sound premolar teeth were collected without cracks, demineralization, or filling material. Teeth were collected from patients seeking orthodontic treatment <30 years and maintained in a 0.1% thymol solution at 4°C without modifying the storage media until the commencement of the study(28).

The teeth were washed and cleaned, and all periodontic ligament and soft tissue were removed using an ultrasonic scaler. Then, the dental crowns of the teeth were polished through micropores with non-fluoridated pumice paste with a low-speed handpiece. Then, the teeth were cleaned with an ultrasonic cleaner to remove all pumice residue for 4 minutes. By fixing the root of the tooth with a mechanics vice, the crown was cut mesiodistally with a water-cooled diamond blade and then cut to obtain square pieces of 4*4 mm from the buccal and from the lingual side from the center of the surface. The samples were poured with acrylic in a silicon mold (the samples were placed on top of the resin mix). The external enamel surface was polished using silicon waterproof abrasive paper (P 800, P 1200, P 2000) underwater to provide flat and smooth surfaces. Then, samples were cleaned ultrasonically to remove all smear layers and stored in de-ionized water in a plastic screw cup at 4°C till used to avoid dehydration(29). All samples underwent a pH cycling procedure to induce the demineralized enamel surface before treatment(30). This procedure consisted of two solutions (the demineralizing and remineralizing solutions). Each sample was placed in a separate plastic cup containing a demineralizing solution for 6 hours, then cleaned with deionized water and placed in another plastic container with a remineralizing solution for 18 hours; all samples were placed inside a water path during the pH cycling procedure to mimic the temperature inside the oral cavity, which was about 37°C. This process was continuous for ten days, so a white spot lesion was formed. The samples were divided into five groups (12 samples in each): 1- control group (with no treatment, samples stored in artificial saliva only (31)), 2- varnish group (samples receive MI varnish treatment only), 3- CO_2 laser group (the samples receive laser treatment only), 4- CO_2 with MI varnish group (sample received laser treatment first, then varnish treatment), and 5- MI varnish with CO_2 laser group (samples receive MI varnish treatment first then laser treatment). The MI varnish was applied by utilizing a tiny applicator brush to apply a single layer of varnish over the enamel surface, allowing it to remain undisturbed for 20 seconds to dry. Subsequently, samples were preserved in artificial saliva for a period of four hours; after that, the varnish layer was removed. This is applied to all groups with MI varnish treatments. A pilot study was conducted to select the most suitable fractional CO_2 laser parameters. The most suitable parameters were 2W power, 10 millisecond (ms) pulse duration, 1 ms interval, 1mm distance, and 20 Hz frequency in non-contact mode. The laser treatment was done for all groups with fractional CO_2 laser treatment (on a dry and clean surface for the CO_2 laser group, before MI varnish in the CO_2 Laser with MI varnish group, after applying MI varnish and removed it before laser treatment in the MI varnish with CO_2 laser group). Afterwards, the samples were kept in artificial saliva at 37°C.

The investigations used were the microhardness test (Vickers hardness microscope) and the profilometer roughness test. Hardness and roughness measurements were taken at every study step (sound enamel, demineralized enamel, and treated samples). Three readings were taken at each test for each sample, and the mean was then calculated. A scanning electron microscope has been used to analyze alterations in the sample's surface morphology. The samples were coated with gold to enhance the resolution of the final image. One sample was examined from each group. The same sample examined for the SEM was used to measure the changes in the element weight of the enamel by using Energy Dispersive Spectroscopy.

3. Results and discussion

3.1. Statistical data analysis

Data were analyzed with statistical analysis software (SPSS). Then, by using Tukey HSD, multiple pairwise comparisons were done between phases of microhardness and surface roughness readings.
The microhardness decreases after demineralization and then increases after the different treatment methods, with significant differences in all phases of demineralization to treatment, except for the control group and the CO_2 laser group, as shown in Table 1.
The microhardness after treatment was higher in the varnish group, followed by the CO_2 laser with varnish group, and lower in all groups with no significant differences. There was a nonsignificant difference between groups in every study phase (Table 1).
In table 2 of the microhardness measurement, there was a significant difference inside each group phase except for the demineralization to the treatment phase of the control group and the demineralization to the treatment phase of the CO_2 group.

Table 1: Descriptive and statistical analysis of surface microhardness across groups, phases, and treatments.

Group	Treatments	H 1		H 2		H 3		F	P value
		Mean	± SD	Mean	± SD	Mean	± SD		
BDT	The Control	337.667	17.607	138.760	39.159	149.600	40.958	162.895	**0.000**
	MI Varnish	356.775	16.358	145.005	23.307	170.075	28.609	536.974	**0.000**
	CO_2 laser	353.892	14.765	141.095	23.846	148.283	18.155	2604.440	**0.000**
	MI with CO_2	352.317	16.999	112.651	20.028	147.108	20.214	347.971	**0.000**
	CO_2 with MI	376.283	13.304	126.153	17.532	150.292	21.955	1335.657	**0.000**
P value		0.052		0.051		0.220			

Table 2 Multiple pairwise comparison of SM among phases using Tukey HSD.

Group	Treatments	Phases	Phases			
			D		T	
			MD	p value	MD	p value
BDT	Control	B	198.907	**0.000**	188.067	**0.000**
		D			-10.840	0.051
	MI Varnish	B	211.770	**0.000**	186.700	**0.000**
		D			-25.070	**0.007**
	CO_2laser	B	212.797	**0.000**	205.608	**0.000**
		D			-7.188	1.000
	MI with CO_2	B	239.666	**0.000**	205.208	**0.000**
		D			-34.457	**0.000**
	CO_2 with MI	B	250.130	**0.000**	225.992	**0.000**
		D			-24.138	**0.000**

In Table 3, regarding surface roughness analysis data, no substantial differences were seen between the groups in any phase of the treatment. In the varnish with CO_2 group, no significant variances were observed between the phases across the same group.
After the treatment, the higher roughness reading was in the varnish group than the control group, and the lowest reading was in the CO_2 laser with the varnish group.
In table 4, the data were non-significant in all phases in the groups except: sound to demineralization in control, varnish group and CO_2 laser with varnish group and from demineralization to treatment phase in CO_2 laser group and varnish group.

Table 3 Descriptive and statistical analysis of surface roughness across groups, phases, and treatments**.**

Phases	Treatments	R1		R2		R3		
		Mean	±SD	Mean	±SD	Mean	±SD	P value
BDT	Control	0.596	0.105	0.830	0.251	0.705	0.151	**0.030**
	MI Varnish	0.675	0.130	0.937	0.251	0.721	0.114	**0.025**
	CO_2laser	0.683	0.066	0.781	0.109	0.674	0.113	**0.033**
	MI with CO_2	0.624	0.082	0.748	0.140	0.700	0.100	0.067
	CO_2 with MI	0.603	0.082	0.729	0.129	0.656	0.126	**0.031**
P value		0.086		0.062		0.709		

Table 4 Multiple pairwise comparison of SM among phases using Tukey HSD.

Group	Treatments	Phases	Phases			
			D		T	
			MD	p value	MD	p value
BDT	control	B	-0.234	**0.022**	-0.109	0.166
		D			0.125	0.242
	MI Varnish	B	-0.262	**0.018**	-0.045	1.000
		D			0.217	**0.030**
	CO_2laser	B	-0.099	0.173	0.009	1.000
		D			0.107	**0.025**
	CO_2 with MI	B	-0.126	**0.032**	-0.053	0.874
		D			0.074	0.832

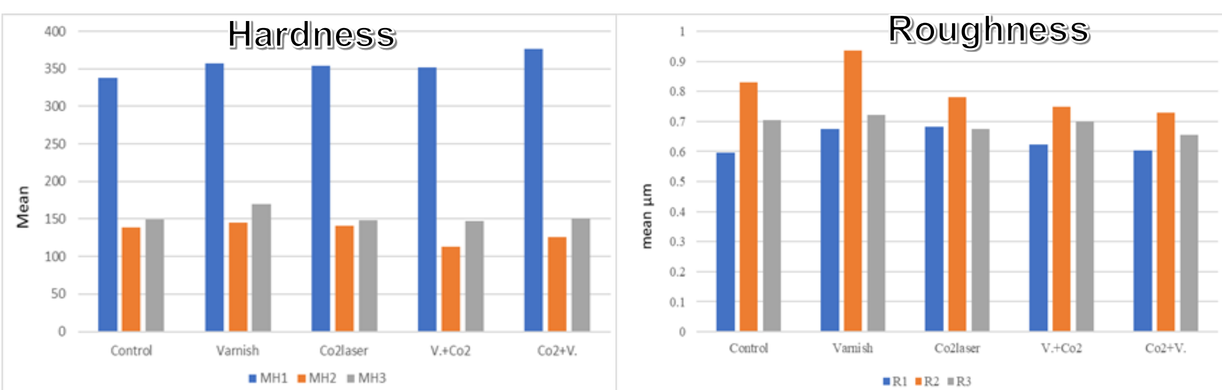

Fig.1 Graphical representation of microhardness and surface roughness data.

3.2. Scanning Electron Microscope and Energy Dispersive Spectroscopy

The sound-polished enamel surface appears smooth and homogenous, with minimal irregularities and debris. The demineralized enamel surface shows porosities and irregularities. The enamel rods lose their organized structure, creating a rough and uneven surface with pitted areas and a loss of the typical prismatic pattern. The surface may also appear more translucent due to reduced mineral content. The group treated with CO_2 laser shows smoother and more uniform characteristics than untreated or demineralized enamel. The laser treatment aids in remineralizing the enamel surface, thereby reducing porosities and irregularities. As a result, you may notice a reformation of the prismatic structure and an improvement in surface integrity. Demineralized enamel surfaces that are treated with an MI varnish typically exhibit fewer porosities and irregularities compared to untreated demineralized enamel. The varnish aids in remineralizing the enamel surface, resulting in a smoother and more uniform appearance. You may also notice a partial reformation of the prismatic structure and an improvement in surface integrity. The synergistic impact of the fractional CO_2 laser and CPP-ACPF varnish on a demineralized enamel surface yields substantial enhancements in surface morphology. SEM images typically show a smoother and more homogeneous surface with fewer irregularities compared to untreated enamel. The prismatic structure of the enamel is partially restored, and the overall integrity of the surface is enhanced, as shown in Fig 2.
The EDX measurement was higher in the sound enamel sample, then decreased after the demineralization process. The calcium weight percentage was the element that decreased; the phosphate decreased slightly. After the treatment, the phosphate weight percentage was slightly changed. The calcium weight percentage was higher in the MI varnish with CO_2 laser group; the rest of the treatment was similar in the results. The carbon weight percentage was higher in sound enamel than in the MI varnish with CO_2 laser group; the rest of the groups were comparable in carbon results, Fig 3 and Table 5.

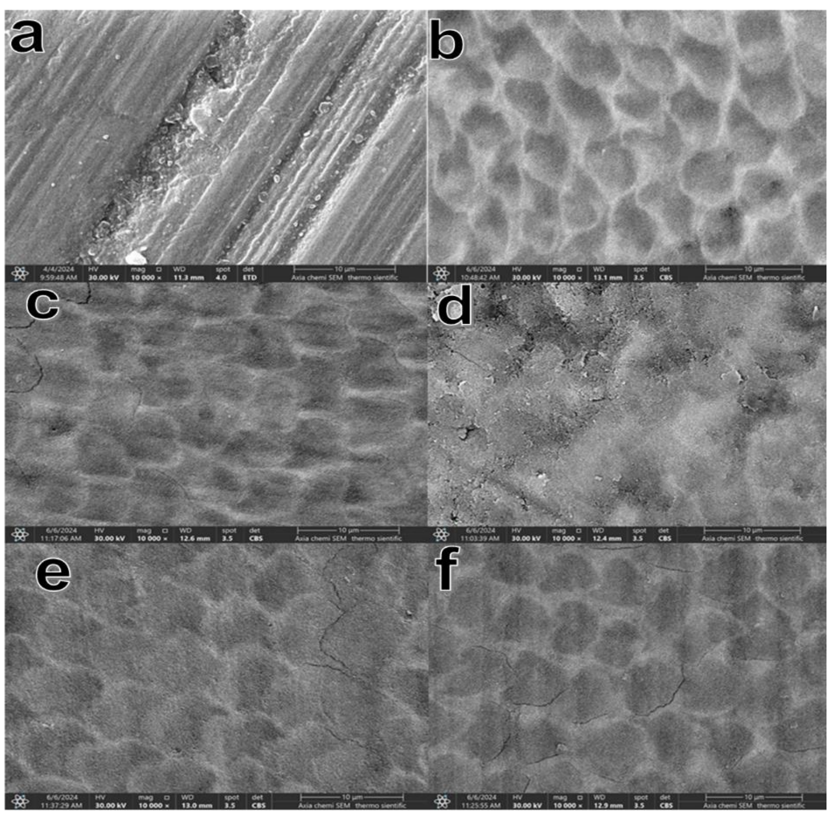

Fig.2 SEM pictures of the enamel surfaces of the groups, **a**: sound enamel, **b**: demineralized enamel, **c**: CO_2 laser varnish treatment, **e**: CO_2 laser with varnish group, **f**: varnish with CO_2 laser group.

Table 5 Elements weight percentage.

samples	Carbon weight %	Phosphate weight %	Calcium weight %
Sound enamel	16.7%	15.9%	44.3%
Demineralized enamel	13.4%	15.2%	35.5%
CO_2 laser	14.6%	15.4%	36.1%
MI varnish	16.4%	15.1%	36.3%
CO_2 Laser with MI varnish	14.7%	15.1%	36.8%
MI varnish with CO_2 Laser	15.1%	15.5%	39

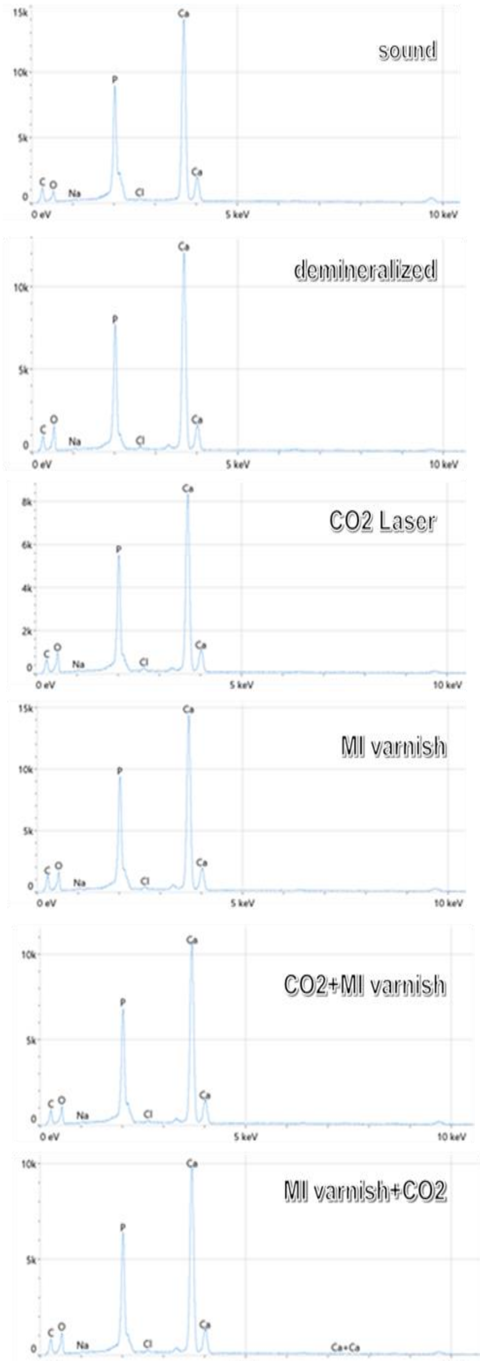

Fig.3 EDX analysis.

3.3. Discussion

This study assessed and analyzed the treatment efficacy of MI varnish (CPP-ACPF) and fractional CO_2 laser on demineralized enamel surfaces. The results suggest that all the treatment approaches effectively enhanced the hardness characteristics of the demineralized enamel surfaces. The null hypothesis was rejected in this investigation. The Vickers microhardness test effectively assesses tooth enamel's microstructure and detects changes in mineral density, indicating mineral loss or gain(32). The results of microhardness testing indicated that demineralization led to a significant reduction in mean hardness compared to the baseline. This reduction may be attributed to enamel weakness caused by an increase in pore size due to the loss of minerals from the enamel surface resulting from the dissolution of hydroxyapatite.

The absorption peak of hydroxyapatite crystal, the main component of dental enamel, matches the wavelength of the CO_2 laser. This means the laser is absorbed and converted to heat without harming surrounding tissues(33). This process will reduce demineralization by decreasing the permeability and acid diffusion of enamel surfaces (34).

The CO_2 laser has been reported to enhance the crystalline stability of enamel, hence reducing its susceptibility to acid and augmenting fluoride absorption by the enamel (35). Chiang et al. indicated that lasing alters the permeability of the enamel matrix. This reduces acid diffusion, while changes in the enamel's organic and inorganic constituents enhance microhardness and diminish acid susceptibility(36). In our present investigation, we employed sub-ablative laser settings. These lasers reduce the solubility of hydroxyapatite and impede the inter-prismatic spaces by melting and recrystallizing enamel prisms on the surface. Furthermore, the administration of fluoride varnish or fluoride gel before radiation exposure might transform enamel hydroxyapatite into fluorapatite, hence reducing enamel solubility. This allows the irradiated surface to retain fluoride ions for a longer duration compared to non-laser irradiated enamel(27).

According to the hardness measurements, there exists a notable disparity in the hardness of combined groups between demineralization measurements and post-treatment assessments, also, the laser's effect on the demineralized enamel surface was not significantly different from the demineralizing measurement in the CO_2 laser group and it's non-significant-from the final measurement that in the control group, in which the samples were placed in artificial saliva only. The use of MI varnish alone demonstrated a high increase in hardness measurement compared to other groups. However, the laser effect significantly decreased surface roughness in the CO_2 laser group and in the CO_2 laser with MI varnish group. The results of EDX show that the sound enamel had a higher mineral percentage, which decreased after the demineralization of the enamel samples. After treatment of different groups, the mineral shows a slight increase after treatment, so it's still far from the sound enamel results. Repeated sessions of treatment are indicated in future works in an attempt to highlight the mineral percentage.

Fluoride products help remineralize teeth by creating more acid-resistant compounds when fluoride ions interact with dental hydroxyapatite crystals(37). This protein nanotechnology incorporates proteins sourced from bovine milk, resulting in the formation of amorphous calcium phosphate (ACP). All calcium phosphates are safe for individuals of all ages, including children, as they dissolve in the stomach upon accidental ingestion, releasing non-toxic calcium and phosphate ions.(38). Numerous dental care products utilizing calcium phosphates are derived from either CPP-ACP or HAP. CPP-ACP sustains a saturated concentration of phosphate and calcium on the enamel surface, hence reducing demineralization and enhancing remineralization(39).

This study employed two combined treatment methods: the application of fractional CO_2 laser before and subsequent to MI varnish on the enamel that was a demineralized surface. The outcomes of these groups were notably comparable; nevertheless, the use of fractional CO_2 laser prior to MI varnish yielded superior results..

The researchers found that using a laser on the enamel surface before applying a remineralizing chemical enhances its effectiveness. One possible explanation is that the laser-created microgaps could be filled with fluoride after application, making it easier to incorporate the ions(40). The concurrent use of CPP-

ACFP and fractional CO_2 laser has been demonstrated to markedly improve tooth microhardness via a potent synergistic effect(22). Laser irradiation enhances fluoride adhesion to dental structures, resulting in elevated fluoride levels in the enamel. Apatite formed in a calcium and phosphorus milieu exhibits reduced carbonate and manganese levels, enhancing its resilience to acid assaults.
Liu et al. assessed the influence of CO_2 laser and fluoride on preventing tooth decay and determined that the laser did not exhibit a synergistic effect with fluoride treatment(41). Farhadian et al. (42) Investigated the impact of CPP-ACP paste and CO_2 laser treatment on the microhardness of demineralized enamel. They found that only the CO_2 laser treatment showed a significant difference from the control group, indicating that CPP-ACP paste was ineffective in preventing demineralization. Additionally, the CO_2 laser alone resulted in higher microhardness values than when combined with CPP-ACP paste, which is incompatible with the present study's findings.
Abufarwa et al. (43) evaluated the impacts of CPP-ACP fluoride varnish and CO_2 laser therapy on enamel demineralization and microhardness. They found that CPP-ACP fluoride varnish is more effective in preventing demineralization. The MI varnish used contains 22000 ppm fluoride, which, along with the CPP-ACP complex, enhances enamel hardness. They reported an increase in hardness to a depth of 60 µm with MI varnish, while the CO_2 laser did not yield encouraging results, which is similar to this study. Baniasad et al. (44) CPP-ACP paste and fractional CO_2 laser, neither alone nor in combination, did not improve the appearance of enamel remineralization compared to the control group. Certain researchers discovered markedly enhanced acid resistance when enamel was subjected to laser irradiation prior to fluoride treatment(45). Conversely, others contended that laser application ought to be conducted subsequent to fluoride therapy(25). Poosti et al. (46) Determined that laser irradiation prior to fluoride treatment significantly enhanced the surface microhardness of enamel, as seen at depths of 30 and 60 µm. Rajendran et al. (47, 48) determined that the concurrent application of CPP-ACP and fluoride exhibits a synergistic impact in the remineralization of enamel samples. Consequently, CPP-ACP with fluoride can be regarded as the preferred material for the remineralization of early enamel carious lesions. The fractional carbon dioxide laser is not explicitly intended for dental use. Additional design enhancements and superior accessories are required to improve comfort during dental treatments.

4. Conclusions

All treatment results had quite similar effects on demineralized enamel by increasing microhardness, decreasing roughness, and enhancing surface morphology, but using a fractional CO_2 laser with MI varnish improved surface roughness more than using them alone.

References

[1] T. Brown, H. E. Lemay, and B. Bursten, Chemistry: The Central Science, 2009.
[2] A. M. Vinogradov, M. Winston, C. J. Rupp, and P. Stoodley, "Rheology of biofilms formed from the dental plaque pathogen Streptococcus mutans," Biofilms, vol. 1, no. 1, pp. 49–56, 2004.
[3] T. G. Fagrell, W. Dietz, B. Jälevik, and J. G. Norén, "Chemical, mechanical and morphological properties of hypomineralized enamel of permanent first molars," Acta Odontol. Scand., vol. 68, no. 4, pp. 215–222, 2010.
[4] K. Elhennawy et al., "Structural, mechanical and chemical evaluation of molar-incisor hypomineralization-affected enamel: A systematic review," Arch. Oral Biol., vol. 83, pp. 272–281, 2017.
[5] G. C. Americano, P. E. Jacobsen, V. M. Soviero, and D. Haubek, "A systematic review on the association between molar incisor hypomineralization and dental caries," Int. J. Paediatr. Dent., vol. 27, no. 1, pp. 11–21, 2017.
[6] J. S. Zhang, C. H. Chu, and O. Y. Yu, "Oral Microbiome and Dental Caries Development," Dent. J. (Basel), vol. 10, no. 10, 2022.
[7] F. A. Crombie, N. J. Cochrane, D. J. Manton, J. E. Palamara, and E. C. Reynolds, "Mineralisation of developmentally hypomineralised human enamel in vitro," Caries Res., vol. 47, no. 3, pp. 259–263, 2013.
[8] G. L. Vogel et al., "Composition of plaque and saliva following a sucrose challenge and use of an alpha-tricalcium-phosphate-containing chewing gum," J. Dent. Res., vol. 77, no. 3, pp. 518–524, 1998.

[9] R. P. Shellis, J. D. Featherstone, and A. Lussi, "Understanding the chemistry of dental erosion," Monogr. Oral Sci., vol. 25, pp. 163–179, 2014.
[10] H. M. Abbas, H. Hamza, and H. M. A. Ahmed (Eds.), Minimal Intervention Approaches in Remineralizing Early Carious Lesions, 2012.
[11] H. H. Xu, M. D. Weir, L. Sun, S. Takagi, and L. C. Chow, "Effects of calcium phosphate nanoparticles on Ca-PO_4 composite," J. Dent. Res., vol. 86, no. 4, pp. 378–383, 2007.
[12] T. Rodemer, N. Pütz, and M. Hannig, "Influence of hydroxyapatite nanoparticles on the formation of calcium fluoride surface layer on enamel and dentine in vitro," Sci. Rep., vol. 12, no. 1, 2022.
[13] D. Dionysopoulos, K. Tolidis, and T. Sfeikos, "Effect of CPP-ACPF and nano-hydroxyapatite preventive treatments on the susceptibility of enamel to erosive challenge," Oral Health Prev. Dent., vol. 17, no. 4, pp. 357–364, 2019.
[14] M. A. Todd, R. N. Staley, M. J. Kanellis, K. J. Donly, and J. S. Wefel, "Effect of a fluoride varnish on demineralization adjacent to orthodontic brackets," Am. J. Orthod. Dentofacial Orthop., vol. 116, no. 2, pp. 159–167, 1999.
[15] H. E. Goodis, D. Fried, S. Gansky, P. Rechmann, and J. D. Featherstone, "Pulpal safety of 9.6 μm TEA CO_2 laser used for caries prevention," Lasers Surg. Med., vol. 35, no. 2, pp. 104–110, 2004.
[16] N. J. Cochrane, P. Shen, Y. Yuan, and E. C. Reynolds, "Ion release from calcium and fluoride containing dental varnishes," Aust. Dent. J., vol. 59, no. 1, pp. 100–105, 2014.
[17] T. T. Thuy et al., "Effect of strontium in combination with fluoride on enamel remineralization in vitro," Arch. Oral Biol., vol. 53, no. 11, pp. 1017–1022, 2008.
[18] K. Chokshi et al., "An in vitro comparative evaluation of three remineralizing agents using confocal microscopy," J. Clin. Diagn. Res., vol. 10, no. 6, pp. ZC39–ZC42, 2016.
[19] M. Esteves-Oliveira, K. F. El-Sayed, C. Dörfer, and F. Schwendicke, "Impact of combined CO_2 laser irradiation and fluoride on enamel and dentin biofilm-induced mineral loss," Clin. Oral Investig., vol. 21, no. 4, pp. 1243–1250, 2017.
[20] B. R. Zancopé et al., "CO_2 laser irradiation enhances CaF_2 formation and inhibits lesion progression on demineralized dental enamel—in vitro study," Lasers Med. Sci., vol. 31, no. 3, pp. 539–547, 2016.
[21] P. Rechmann, L. Q. Le, R. Kinsel, C. Kerbage, and B. M. T. Rechmann, "In vitro CO_2 9.3-μm short-pulsed laser caries prevention—effects of a newly developed laser irradiation pattern," Lasers Med. Sci., vol. 35, no. 4, pp. 979–989, 2020.
[22] S. M. Adel, E. S. Marzouk, and N. El-Harouni, "Combined effect of Er,Cr:YSGG laser and casein phosphopeptide amorphous calcium phosphate on the prevention of enamel demineralization," Angle Orthod., vol. 90, no. 3, pp. 369–375, 2020.
[23] N. Yilmaz et al., "Effect of the usage of Er,Cr:YSGG laser with and without different remineralization agents on the enamel erosion of primary teeth," Lasers Med. Sci., vol. 35, no. 7, pp. 1607–1620, 2020.
[24] S. Ghadimi, M. Khami, and S. Razeghi, "Combined effect of laser irradiation and fluoride application in dental caries prevention," J. Dent. Med. Tehran Univ. Med. Sci., 2015.
[25] M. Esteves-Oliveira et al., "Rehardening of acid-softened enamel and prevention of enamel softening through CO_2 laser irradiation," J. Dent., vol. 39, no. 6, pp. 414–421, 2011.
[26] M. Mahmoudzadeh et al., "Effect of CO_2 laser on the prevention of white spot lesions during fixed orthodontic treatment: A randomized clinical trial," Turk. J. Orthod., vol. 32, no. 3, pp. 165–171, 2019.
[27] K. M. Ramalho et al., "Protective effect of CO_2 laser (10.6 μm) and fluoride on enamel erosion in vitro," Lasers Med. Sci., vol. 28, no. 1, pp. 71–78, 2013.
[28] A. Secilmis, E. Dilber, N. Ozturk, and F. G. Yilmaz, "The effect of storage solutions on mineral content of enamel," Mater. Sci. Appl., vol. 4, no. 7, pp. 7–12, 2013.
[29] J. Parry, L. Shaw, M. J. Arnaud, and A. J. Smith, "Investigation of mineral waters and soft drinks in relation to dental erosion," J. Oral Rehabil., vol. 28, no. 8, pp. 766–772, 2001.
[30] M. Alghazali, F. Abdul-Razzak, M. Al-Bazaz, N. Jafer, M. Radhi, and K. Hubeatir, "Effect of CO_2 laser and selected nanoparticles on the microhardness of human dental enamel in vitro study," J. Med. Chem. Sci., vol. 6, no. 7, pp. 1487–1497, 2023.
[31] M. Björklund, A. C. Ouwehand, and S. D. Forssten, "Improved artificial saliva for studying the cariogenic effect of carbohydrates," Curr. Microbiol., vol. 63, no. 1, pp. 46–49, 2011.
[32] W. A. Fried, M. Abdelaziz, C. L. Darling, and D. Fried, "High contrast reflectance imaging of enamel demineralization and remineralization at 1950-nm for the assessment of lesion activity," Lasers Surg. Med., vol. 53, no. 7, pp. 968–977, 2021.

[33] F. M. Bevilácqua, D. M. Zezell, R. Magnani, P. A. Ana, and C. P. Eduardo, "Fluoride uptake and acid resistance of enamel irradiated with Er:YAG laser," Lasers Med. Sci., vol. 23, no. 2, pp. 141–147, 2008.
[34] M. Shubbar, A. Addie, and L. Al-Taee, "The effect of a bioactive oral system and CO_2 laser on enamel susceptibility to acid challenge," Diagnostics (Basel), vol. 13, no. 6, 2023.
[35] A. Mathew et al., "Acquired acid resistance of human enamel treated with laser (Er:YAG laser and CO_2 laser) and acidulated phosphate fluoride treatment: An in vitro atomic emission spectrometry analysis," Contemp. Clin. Dent., vol. 4, no. 2, pp. 170–175, 2013.
[36] Y. C. Chiang et al., "Microstructural changes of enamel, dentin-enamel junction, and dentin induced by irradiating outer enamel surfaces with CO_2 laser," Lasers Med. Sci., vol. 23, no. 1, pp. 41–48, 2008.
[37] A. Lussi et al., "The use of fluoride for the prevention of dental erosion and erosive tooth wear in children and adolescents," Eur. Arch. Paediatr. Dent., vol. 20, no. 6, pp. 517–527, 2019.
[38] J. Enax, F. Meyer, E. Schulze Zur Wiesche, and M. Epple, "On the application of calcium phosphate micro- and nanoparticles as food additive," Nanomaterials (Basel), vol. 12, no. 22, 2022.
[39] P. Somasundaram, N. Vimala, and L. G. Mandke, "Protective potential of casein phosphopeptide amorphous calcium phosphate containing paste on enamel surfaces," J. Conserv. Dent., vol. 16, no. 2, pp. 152–156, 2013.
[40] F. A. R. M. Al-Bazaz, M. H. Radhi, N. J. Hubeatir, and M. W. Alghazali, "Effect of CO_2 laser and selected nanoparticles on the microhardness of human dental enamel in vitro study," J. Med. Chem. Sci., vol. 6, no. 7, pp. 1487–1497, 2023.
[41] Y. Liu, C. Y. Hsu, C. M. Teo, and S. H. Teoh, "Potential mechanism for the laser-fluoride effect on enamel demineralization," J. Dent. Res., vol. 92, no. 1, pp. 71–75, 2013.
[42] N. Farhadian et al., "Effect of CPP-ACP paste with and without CO_2 laser irradiation on demineralized enamel microhardness and bracket shear bond strength," Dental Press J. Orthod., vol. 22, no. 4, pp. 53–60, 2017.
[43] M. Abufarwa, A. Noureldin, T. Azimaie, P. M. Campbell, and P. H. Buschang, "Preventive effects of carbon dioxide laser and casein phosphopeptide amorphous calcium phosphate fluoride varnish on enamel demineralization: A comparative, in vitro study," J. Investig. Clin. Dent., vol. 10, no. 2, p. e12400, 2019.
[44] N. Baniasad, M. Poosti, S. Etemadi, F. Mahmoudi, and K. Mirmohammadi, "Effects of fractional carbon dioxide laser and CPP-ACP paste on remineralization and discoloration of enamel white spot lesions," J. Res. Dent. Maxillofac. Sci., vol. 9, no. 3, pp. 174–183, 2024.
[45] S. Tagomori and T. Morioka, "Combined effects of laser and fluoride on acid resistance of human dental enamel," Caries Res., vol. 23, no. 4, pp. 225–231, 1989.
[46] M. Poosti, F. Ahrari, H. Moosavi, and H. Najjaran, "The effect of fractional CO_2 laser irradiation on remineralization of enamel white spot lesions," Lasers Med. Sci., vol. 29, no. 4, pp. 1349–1355, 2014.
[47] R. Rajendran et al., "Comparative evaluation of remineralizing potential of topical cream containing casein phosphopeptide-amorphous calcium phosphate and casein phosphopeptide-amorphous calcium phosphate with fluoride: An in vitro study," J. Pharm. Bioallied Sci., vol. 16, suppl. 2, pp. S1801–S1804, 2024.
[48] R. Rajendran et al., "Development of strontium-doped nano hydroxyapatite dentifrice and compare its remineralising potential with a topical cream containing casein phosphopeptide-amorphous calcium phosphate – An in vitro study," Indian J. Dent. Res., vol. 32, no. 1, pp. 92–97, 2021.

دراسة مختبرية: تأثير ورنيش MI وليزر ثنائي أوكسيد الكاربون الجزئي على سطح المينا منزوعة المعادن

آيات ماجد صالح [1]، اسيل جاسم علي [2]، سؤدد سلمان احمد [3]

[1]معهد الليزر للدراسات العليا، جامعة بغداد، بغداد، العراق.
[2]قسم طب الفم، كلية طب الاسنان، الجامعة المستنصرية، بغداد، العراق.
[3]قسم الفيزياء، كليه العلوم، جامعة بغداد، بغداد، العراق.

البريد الالكتروني للباحث : ayatalsaraj@gmail.com

الخلاصة: تقييم التأثيرات العلاجية لليزر ثنائي اوكسيد الكاربون الجزئي وورنيش MI وحدهما وتأثيراتهما مجتمعة في حالتين (ليزر ثنائي أوكسيد الكاربون قبل وبعد تطبيق ورنيش MI). الطريقة: تم تحضير 60 عينة مينا ، ثم تم تمرير العينات من خلال عملية تقليل نسبه المعادن للحصول على سطح مينا منزوع المعادن. تم تقسيم العينات إلى خمس مجموعات: مراقبه ، ليزر ثنائي أوكسيد الكاربون ، ورنيش MI ، ليزر ثنائي أوكسيد الكاربون + ورنيش MI وورنيش MI + ليزر ثنائي أوكسيد الكاربون. تم تقييم التغيرات السطحية بواسطة جهاز قياس الصلابة و قياس خشونة السطح و استخدام المجهر الإلكتروني الماسح مع التحليل الطيفي للأشعة السينية المشتتة للطاقة (SEM-EDX). النتائج: انخفضت جميع نتائج الصلابة بعد عملية إزالة المعادن ثم زادت بعد المعالجات المختلفة مع عدم وجود فرق كبير بين المجموعات المعالجة. كانت بيانات خشونة السطح أفضل في المجموعات المحتوية على ليزر ثنائي أوكسيد الكاربون. تم تحسين سطح المينا ونسبه المعادن بعد العلاجات. الاستنتاج: كانت جميع مجموعات العلاج فعالة في تعزيز الصلابة وتقليل الخشونة و تحسين مورفولوجيا السطح مقارنة بمجموعة المراقبة، مع تفضيل الاستخدام المشترك لليزر ثنائي أوكسيد الكاربون وورنيش MI في كلتا الحالتين (نتائج مماثلة).