Original Article

Efficacy of Bioactive Glass Nanoparticles and Er,Cr: YSSG Laser in Management of Dentin Hypersensitivity (In *vitro* study)

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ABSTRACT

Introduction: Dentin hypersensitivity is a painful dental issue known with a transient and intense pain, when the exposed dentin reacts to various stimuli. Bioactive glass and multiple types of lasers have been tested in treating dentin hypersensitivity. Yet, none have combined them together in occluding exposed dentinal tubules.

Aim of the Study: The current study focused on evaluating the effect of erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser with wavelength 2780 nm and bioactive glass nanoparticles paste either each alone or in combination with different sequences; on dentinal tubules closure.

Methods: Forty healthy extracted premolar teeth were used for this study. They were distributed equally into a control group and 4 experimental groups. Control group: received no treatment. Nano-Bioactive glass group: treated with nano-bioactive glass paste only, Er,Cr:YSGG laser group: received laser irradiation only, Er,Cr:YSGG laser + nano-bioactive glass group: treated with nano-bioactive glass paste after laser irradiation. Nano-bioactive glass + Er,Cr:YSGG laser group: treated with nano-bioactive glass paste before laser irradiation. Dentin samples were evaluated morphologically by scanning electron microscope, with subsequent analysis of the mean diameter of dentinal tubules, and calcium and phosphorous analysis by energy dispersive X-ray spectroscopy.

Results: Nano-bioactive glass + Er,Cr:YSGG laser group showed notably improved dentinal tubules closure in comparison to the other groups through scanning electron microscope imaging. The results were confirmed by the energy dispersive X-ray analysis which revealed the highest calcium and phosphorus weight %, in addition to recording the lowest mean diameter of dentinal tubules.

Conclusion: The application of nano-bioactive glass and, Er,Cr:YSGG laser and the combination of both provided a satisfactory dentinal tubular closure. However, combining both nano-bioactive glass and Er,Cr:YSGG laser was found to be more efficient with superior results, rather than using each modality alone.

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Key Words: Bioactive glass, Cr:YSGG laser, dentin, dentinal tubules, Er.

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INTRODUCTION

Dentin hypersensitivity (DH) is described as a discomfort originating from open tubules and exposed dentin. It usually results from mechanical, thermal, or chemical stimuli and is unrelated to any other dental pathology or defect[1,2]. Several dental professionals encounter difficulties in identifying the causes, diagnosing, and effectively managing dental hypersensitivity, revealing certain limitations in this domain.[3] This dental issue can have a substantial impact on an individual's quality of life, leading to; changes in eating habits, the avoidance of specific food or drinks, and higher anxiety or discomfort during dental operations.[4]

To block or close dentinal tubules, various agents can be applied locally, either by dentists or at home. Through the formation of precipitates on the exposed dentin surfaces, these desensitizing agents effectively seal off the dentinal tubules.[5] Various studies have identified desensitizing pastes like potassium nitrate, sodium fluoride, and calcium hydroxide that have shown effectiveness in reducing DH. However, achieving a permanent cure for DH remains a challenge. Bioactive glass (BG) is considered as a promising agent for promoting the formation of reparative dentin, which serves as a biologic barrier surrounding dentinal tubules. The limited permeability of reparative dentin restricts the transmission of harmful substances from the dentinal tubules to the dental pulp and decreases the flow of dentinal fluid, hence minimizing dentin hypersensitivity. Consequently, BG application to the exposed dentin surface may provide a durable DH treatment option.[6]

In the past years, a new treatment approach utilizing lasers has emerged. The use of lasers for treating DH was first introduced in 1985, and since then, numerous investigations have been conducted to determine the

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efficacy of laser therapy in treating DH. Some of commonly used laser are neodymium-doped yttrium aluminum garnet (ND: YAG), Erbium-doped yttrium-aluminum-garnet (Er:YAG), carbon dioxide (CO_2), and gallium aluminum arsenide(Ga-Al-As). The efficacy of their desensitizing effect ranged from 2.5 to 100%, depending on the type of laser used and application parameters[7] The erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr;YSGG) laser is commonly used for treating DH. The laser's emission at a wavelength of 2780 nm is primarily taken up by water and hydroxyapatites' hydroxyl ions. This can cause physical and chemical changes in the dentin structure, including melting and recrystallization.[8]

Laser interaction with dentinal tubules involves a mechanism known as photomechanical ablation. In the course of this, laser energy is absorbed by water present in the dentin, resulting in the formation of high-pressure microbubbles. These microbubbles create a mechanical disturbance in the adjacent tissue, facilitating the removal of debris and the closure or sealing of dentinal tubules. Moreover, lasers can bring about thermal modifications in the dentin, causing changes in its structure and the closure of tubules. The specific interaction mechanism may differ according to the kind of laser employed and its specific parameters.[9,8,10]

Other previous studies discussed the application of BG and ER; CR, YSGG laser for the treatment of DH. Yet, none have incorporated them together with different sequences of application in occluding exposed dentinal tubules. Thus, the goal of the current study was to compare the efficacy of ER; CR, YSGG laser and BG nanoparticles (nanoBG) alone and their combination with different sequences to evaluate dentinal tubules' occlusion in DH under scanning electron microscopic imaging and energy- dispersive X-ray spectroscopy analysis.

MATERIALS AND METHODS

Dentin specimen setting up and grouping

A total of 40 human extracted sound premolars teeth free from caries, restorations, or fractures were collected, from three dental clinics at 6th of October city, Cairo, Egypt. Teeth were extracted from 20- to 35-year-old patients for orthodontic treatments. Since the specimens were extracted teeth, ethical committee approval was not required for this research. The samples were cleaned and stored in deionized water for this study. Dentin discs were prepared from the crown, with a 2 mm thickness. All teeth had been cut with an Isomet 4000; very thin diamond disc perpendicular to long axis of the tooth. Finally, sound dentin surface was obtained in eighty halves.[11,12]

For the purpose to simulate the sensitivity of dentin surface, each specimen was submerged in 17% EDTA solution (El-Gomhouria co., Egypt) for two minutes. Subsequently, they were given a 30-seconds distilled water rinse, revealing open dentinal tubules.[13] Samples were divided equally and at random into a control and 4 experimental groups as the following:

Control group: consisted of 16 halves of dentin discs with no treatment.

NanoBG group: consisted of 16 halves of dentin discs treated with nanoBG paste (NanoTech, Egypt).

Er,Cr:YSGG laser group: consisted of 16 halves of dentin discs treated with ER;CR:YSSG laser irradiation.

Er,Cr:YSGG laser + nanoBG group: consisted of 16 halves of dentin discs treated with ER;CR:YSSG laser irradiation followed by nanoBG paste application.

NanoBG group + Er,Cr:YSGG laser: consisted of 16 halves of dentin discs treated with nanoBG paste followed by laser irradiation.

Bioactive glass application

Bioactive glass nanoparticles used in the current study were prepared by; NanoTech Egypt. It was prepared by sol-gel method to reach the composition of 60SiO2:35CaO:5P2O5.[14] The average size of the BG nanoparticles was between 50.46 and 70.36 nm (Figure 1) A rotating brush was used for 15 seconds at a low speed to apply nanoBG paste.[15,16]

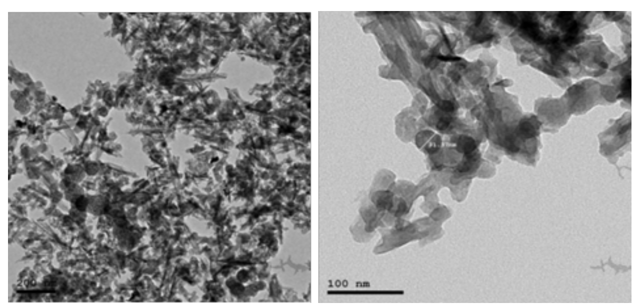

Fig. 1: Transmission electron micrograph of nano bioactive glass particles showing their average particle size.

Er,Cr:YSGG Laser application

Er,Cr:YSGG laser with wavelength 2780 nm was utilized. The Er,Cr:YSGG laser system applied was a Biolase Waterlase MD (Measure Distance) fitted with a fiber-tipped 'Gold' handpiece and scanning movement (back and forth). The sapphire tip was used to deliver the laser. Straight handpiece [MGG6] and the laser tip was held perpendicular to the irradiated surface defocused 1 mm, in a non-contact mode and continuous wave beam with 0% water and 0% air to prevent contamination of dentin. Each area was irradiated for 30 seconds power 0.25 W, frequency 20 Hz, pulse duration 140 µs, spot area 600 µm.

Following the interventions, all the experimental dentin specimens were stored in artificial saliva (1.5 mM/1 CaCl2, 50mM/1 KCl, 0.9mM/1 KH2 PO4, and adjusted pH= 7.4) (NanoTech, Egypt). They were kept in incubator for 24 hours in temperature of 37oC before assessment.[17]

Scanning Electron Microscope (SEM)/Energy Dispersive X-ray (EDX) evaluation

Dentin discs were mounted on conductive aluminum pin stubs with electro-conductor carbon glue prior to SEM analysis. The used SEM Model was Quanta FEG 250 (Field Emission Gun) attached with EDX unit, with accelerating voltage 30 K.V. at the Egyptian mining and mineral research center. All samples were examined morphologically using SEM at magnifications of (x2500), (x5000), and (x6000). The EDX analysis system worked as an integrated feature of the used SEM models attached with EDX unit. The elemental distribution of phosphorus and calcium was calculated from the dentin specimen.

Mean diameter of the dentinal tubule measurement

SEM images of magnification (x6000) were used for morphometric analysis. Image analysis was done by employing the image analysis program Image J (Image J 1.53d) via blinded assessor. As previously described by Gholami *et al*;[11] the mean diameter of the dentinal tubules was assessed for each SEM image for each specimen of all studied groups.

Statistical analysis

The mean and standard deviation (SD) were employed to explain the data from the EDX analysis and the measurements of the dentinal tubules' average diameter. The normality test revealed that the data were distributed normally. The ANOVA test and the multiple comparison Tukey post-hoc test were used to analyze the data. A *p value* of lower than 0.05 indicated that the findings were statistically significant. Version 22 of the statistical software was used to analyze the data.

RESULTS

Scanning Electron Microscopic results

Transverse sections of dentin discs in the control group, captured by SEM micrographs showed the typical etched dentinal tubules without smear layer. The dentinal tubules appeared patent and widely opened. The dentinal tubules orifices were surrounded by peritubular dentin and they were separated from each other by intertubular dentin. (Figures 2 A,B) While, the SEM micrographs of the nanoBG group revealed allover opened dentinal tubules with precipitation of nanoBG material on the specimens' surface. (Figure 3A) Closer view of nanoBG group specimen revealed partially occluded dentinal tubules with BG nanoparticles. Nevertheless, a limited quantity of dentinal tubules was completely occluded with nanoBG paste. (Figure 3B) The dentin specimens lased by Er,Cr:YSGG laser revealed a major narrowing of dentinal tubules' orifices. (Figure 3C) A higher magnification of laser irradiated discs revealed some completely sealed dentinal tubules with signs of dentin melting, while others appeared constricted. (Figure 3D)

SEM micrographs of Er,Cr:YSGG laser+ nanoBG group clearly demonstrated a decrease in the diameter of the dentinal tubules. (4A) At higher magnification many dentinal tubules presented complete closure with accumulation of BG nanoparticles, while some dentinal tubules exhibited narrowing. (Figures 4 A,B) SEM micrographs of dentin disc treated with nanoBG followed by laser irradiation showed a huge areas of melted dentin islands with minerals deposits on the dentin surface and areas of concentration of nano-BG paste. (Figures 4 C,D) At a higher magnification, the specimens revealed areas of completely occluded dentinal tubules with melted dentin enclosing lumen of dentinal tubules with mineralized matrix deposition forming occlusion plugs. A noticeable sealing of most of the dentinal tubules was detected, while some dentinal tubules were partially sealed with the presence of agglomerations of BG nanoparticles on the surface. (Figure 4D)

EDX and Statistical Analysis Results

Calcium and Phosphorus weight percent statistical analysis

The EDX evaluation revealed that the highest mean of calcium and phosphorous Wt% was detected in nanoBG +laser group, while the lowest value was detected in control group. Pairwise comparison revealed a significant increase in the mean of calcium and phosphorous Wt% in nanoBG+laser group compared to laser, laser+nanoBG, nanoBG, and control groups, displaying a statistically significant difference between groups (p<0.05). A significantly higher mean was also recorded in laser + nanoBG group as compared to nanoBG and control groups. In a comparable manner, the laser group's mean was found to be significantly higher than that of the nanoBG and control groups. (Tables 1,2,3,4, Figures 5 A,B).

Diameter of dentinal tubules

The statistical analysis of the mean diameter of dentinal tubules showed that the highest average dentinal tubule diameter was recorded in control group. Meanwhile, the group which recorded the lowest value was nanoBG+laser with a statistically significant difference as compared to the other groups (p<0.05). Additionally, pairwise comparison showed significantly higher value in nanoBG group and laser group as compared to both nanoBG +laser and laser + nanoBG groups. However, the difference between nanoBG and laser groups as well as the difference between laser + nanoBG and nanoBG +laser groups lacked statistical significance. (Tables 5,6, Figure 5C).

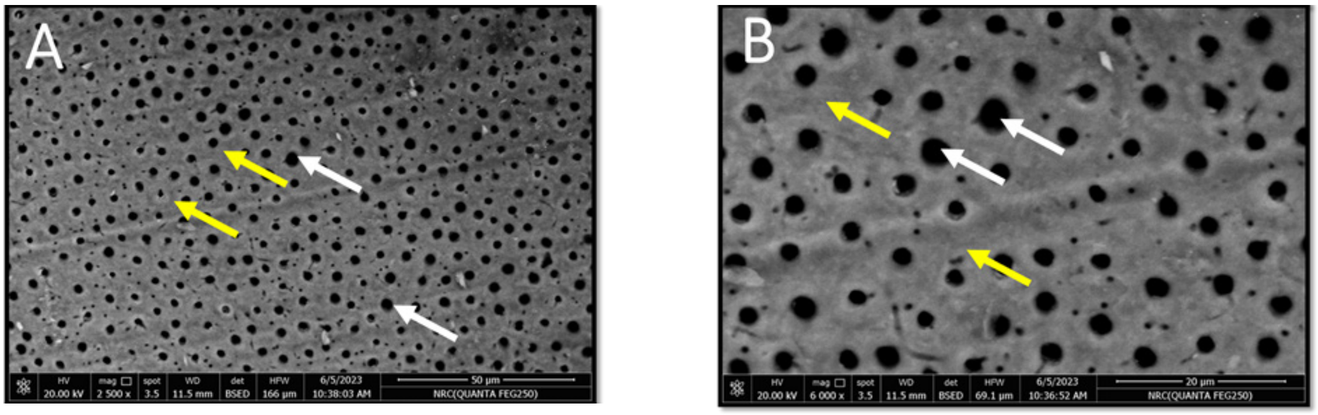

Fig. 2: SEM micrographs of dentin specimen of control group. White arrows: open dentinal tubules. Yellow arrows: intertubular dentin. (A: Orig. mag. x2500, B: Orig. mag. x6000).

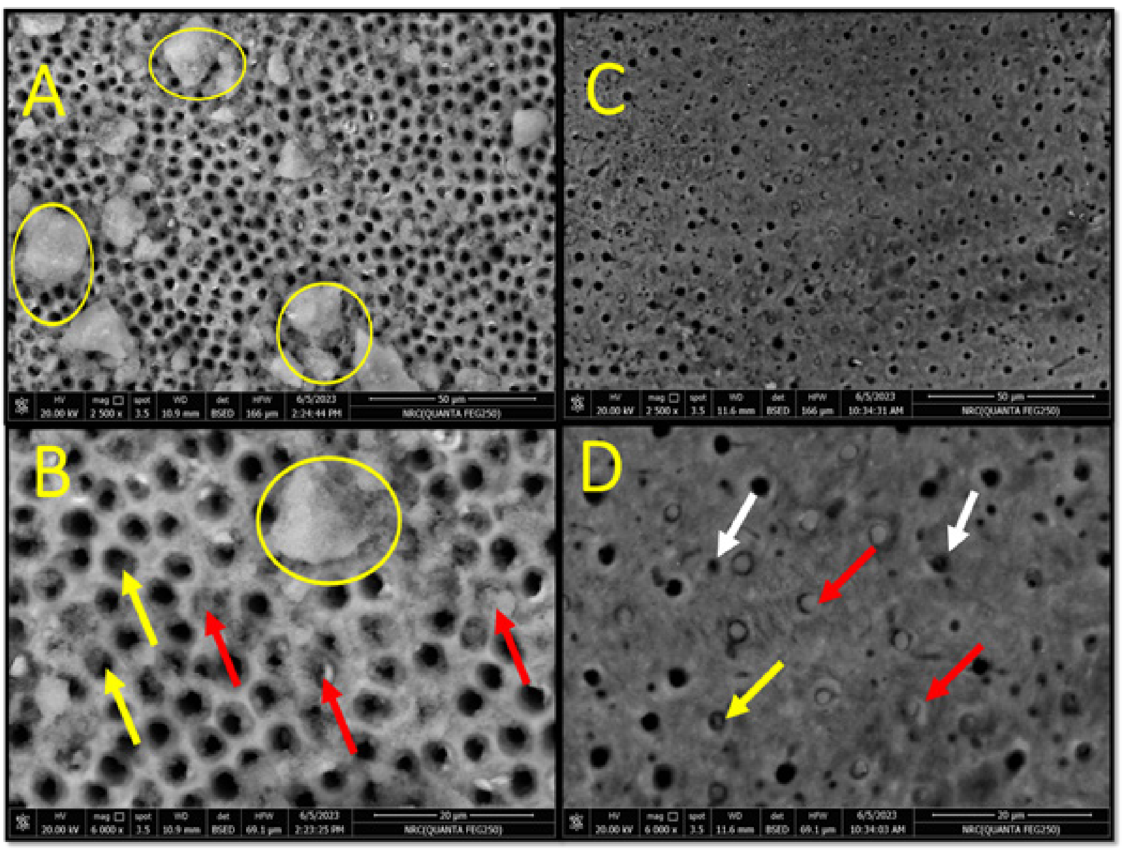

Fig. 3: SEM micrographs of dentin specimen of nano-BG group (A, B) and Er,Cr:YSSG laser group (C,D). Yellow arrows: partially occluded dentinal tubules. Red arrows: total occlusion of dentinal tubules. White arrows: narrowing of dentinal tubules. Yellow circles: BG nanoparticles aggregations. (A & C: Orig. mag. x2500, B & D: Orig. mag. x6000)

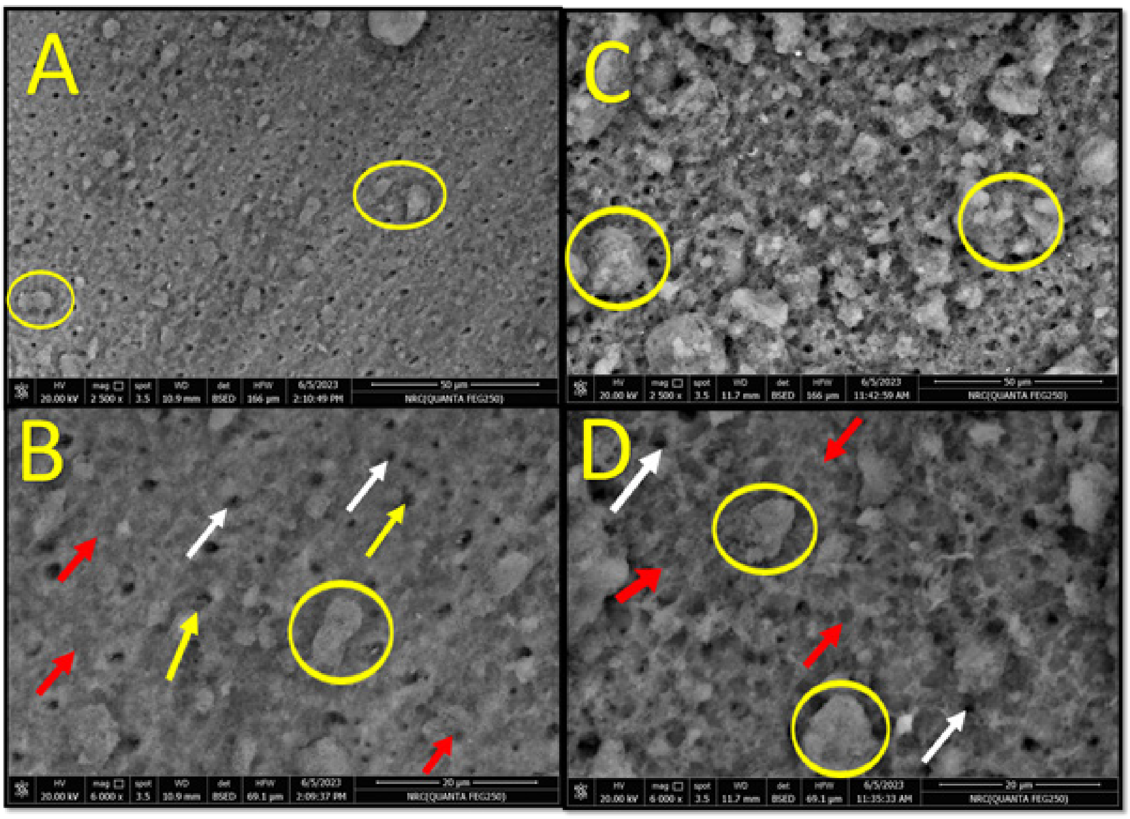

Fig. 4: SEM micrographs of dentin specimen of Laser + nano-BG group (A, B) and Nano-BG + laser group (C, D). Yellow arrows: partially occluded dentinal tubules. Red arrows: total occlusion of dentinal tubules. White arrows: narrowing of dentinal tubules. Yellow circles: BG nanoparticles aggregations. (A & C: Orig. mag. x2500, B & D: Orig. mag. x6000)

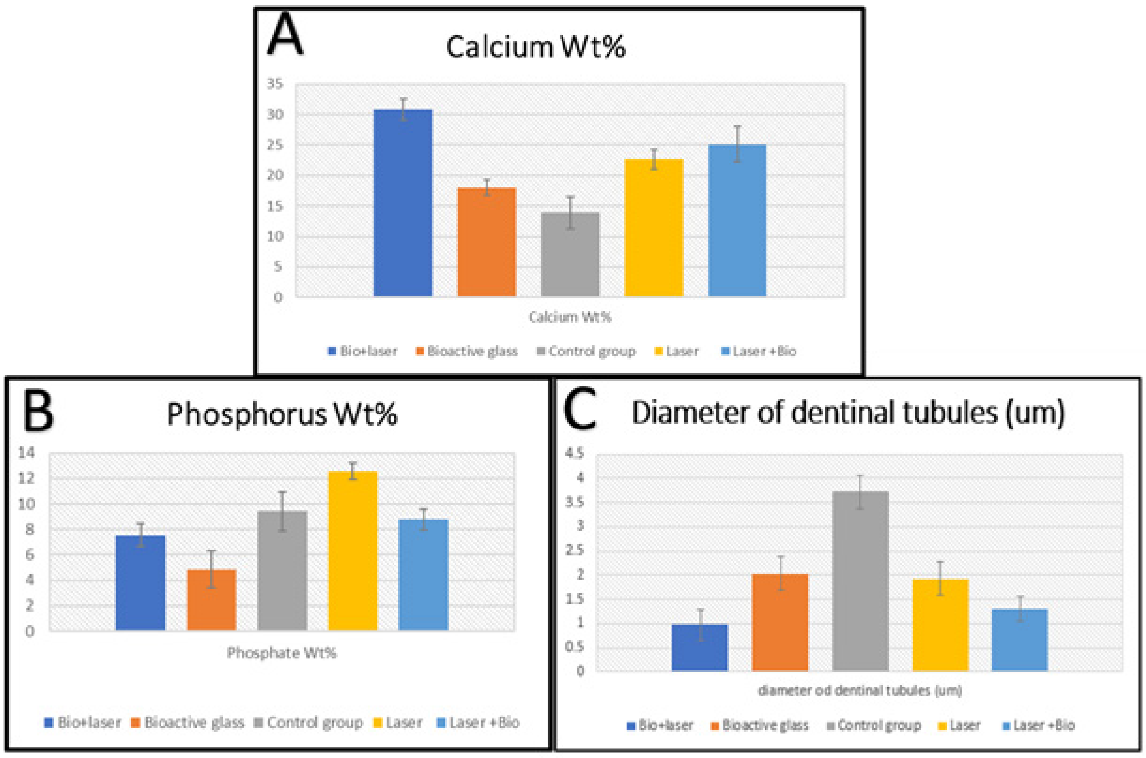

Fig. 5: Bar chart showing mean value for Calcium Wt% (A), Phosphorus Wt% (B), diameter of dentinal tubules (C) with SD error bars.

Table 1: Descriptive statistics and comparison between groups for Calcium Wt%, (ANOVA test).

Parameter	Group	Mean	Std. Error	95% Confidence Interval for Mean	One way ANOVA	
					F	*P value*
Calcium Wt%	Control group	13.921±2.589 D	0.819	(12.580,15.262)	95.00	0.000*
	nanoBG	18.012±1.267 C	0.401	(16.671,19.353)		
	Laser	22.642±1.599 B	0.506	(21.301,23.983)		
	Laser + nanoBG	25.101±2.880 B	0.911	(23.760,26.442)		
	nanoBG+laser	30.790±1.732 A	0.548	(29.449,32.131)		

Significance level *P*<0.05, *significant.

Table 2: Detailed results of Tukey's post hoc test for pairwise comparison between groups for Calcium Wt%.

Parameter	Difference of Levels		95% Confidence Interval	T-Value	Adjusted *P-Value*
Calcium Wt%	nanoBG	nanoBG +laser	(-15.454, -10.102)	-13.57	0.000*
	Control group	nanoBG +laser	(-19.545, -14.193)	-17.92	0.000*
		nanoBG	(-6.767, -1.415)	-4.35	0.001*
	Laser	nanoBG +laser	(-10.824, -5.472)	-8.65	0.000*
		nanoBG	(1.954, 7.306)	4.92	0.000*
		Control group	(6.045, 11.397)	9.26	0.000*
	Laser + nanoBG	nanoBG +laser	(-8.365, -3.013)	-6.04	0.000*
		nanoBG	(4.413, 9.765)	7.53	0.000*
		Control group	(8.504, 13.856)	11.87	0.000*
		Laser	(-0.217, 5.135)	2.61	0.085

Table 3: Descriptive statistics and comparison between groups for Phosphorus Wt% (ANOVA test).

Parameter	Group	Mean	Std. Error	95% Confidence Interval for Mean	One way ANOVA	
					F	*P value*
Phosphorus Wt%	Control group	4.846±1.471 E	0.465	(3.869, 5.823)	157.56	0.000*
	nanoBG	9.722±2.346 D	0.742	(8.745, 10.699)		
	Laser	12.261±0.802 C	0.254	(11.284, 13.238)		
	Laser + nanoBG	17.518±1.324 B	0.419	(16.541, 18.495)		
	nanoBG+laser	20.081±1.304 A	0.412	(19.104, 21.058)		

Significance level *P*<0.05, *significant

Table 4: Detailed results of Tukey's post hoc test for pairwise comparison between groups for Phosphorus Wt%.

Parameter	Difference of Levels		95% Confidence Interval	T-Value	Adjusted *P-Value*
Phosphorus Wt%	nanoBG	nanoBG +laser	(-12.309, -8.409)	-15.10	0.000*
	Control group	nanoBG +laser	(-17.185, -13.285)	-22.21	0.000*
		nanoBG	(-6.826, -2.926)	-7.11	0.000*
	Laser	nanoBG +laser	(-9.770, -5.870)	-11.40	0.000*
		nanoBG	(0.589, 4.489)	3.70	0.005*
		Control group	(5.465, 9.365)	10.81	0.000*
	Laser + nanoBG	nanoBG +laser	(-4.513, -0.613)	-3.74	0.005*
		nanoBG	(5.846, 9.746)	11.37	0.000*
		Control group	(10.722, 14.622)	18.47	0.000*
		Laser	(3.307, 7.207)	7.66	0.000*

Significance level *P*<0.05, *significant

Table 5: Descriptive statistics and comparison between groups for diameter of dentinal tubules (um) (ANOVA test).

Parameter	Group	Mean	Std. Error	95% Confidence Interval for Mean	One way ANOVA	
					F	*P value*
Diameter of dentinal tubules (um)	Control group	3.724±0.354 A	0.112	(3.516, 3.932)	106.23	0.000*
	nanoBG	2.029±0.348 B	0.110	(1.821, 2.236)		
	Laser	1.924±0.349 B	0.110	(1.716, 2.132)		
	Laser + nanoBG	1.2991±0.2498 C	0.0790	(1.0913, 1.5069)		
	nanoBG+laser	0.973±0.320 C	0.101	(0.765, 1.181)		

Significance level $P<0.05$, *significant

Table 6: Detailed results of Tukey's post hoc test for pairwise comparison between groups for diameter of dentinal tubules (um).

Parameter	Difference of Levels		95% Confidence Interval	T-Value	Adjusted *P-Value*
Diameter of dentinal tubules (um)	nanoBG	nanoBG +laser	(0.641, 1.470)	7.23	0.000*
	Control group	nanoBG +laser	(2.336, 3.166)	18.85	0.000*
		nanoBG	(1.281, 2.110)	11.62	0.000*
	Laser	nanoBG +laser	(0.536, 1.366)	6.52	0.000*
		nanoBG	(-0.519, 0.310)	-0.72	0.952
		Control group	(-2.215, -1.385)	-12.34	0.000*
	Laser + nanoBG	nanoBG +laser	(-0.089, 0.741)	2.23	0.186
		nanoBG	(-1.144, -0.315)	-5.00	0.000*
		Control group	(-2.840, -2.010)	-16.62	0.000*
		Laser	(-1.040, -0.210)	-4.28	0.001*

Significance level $P<0.05$, *significant.

DISCUSSION

Dentin hypersensitivity is a frequent dental disorder in oral health where individuals experience intense discomfort, when the exposed dentin is subjected into stimuli such as touch, heat, changes in osmotic pressure, or specific chemicals.[18] The hydrodynamic theory states that the dentinal fluid movement in the dentinal tubules, causes dentin sensitivity and the pain that the nerves experience. The quantity of exposed dentinal tubules is linked to the intensity of dentin hypersensitivity.[19] Kara *et al*.;[20] supposed that younger people exhibit a greater increase in dental sensitivity, since older people's tubule diameters are smaller. Consequently, extracted teeth from patients aged 20 to 35 were used for this study. In order to simulate dentin hypersensitivity, the dentinal tubules were opened using EDTA.[21]

Numerous studies have compared the efficiency of laser treatment with conventional modalities for treating dentin hypersensitivity. The dentin hypersensitivity has been significantly reduced by Er:YAG and Er,Cr:YSGG lasers.[22] Single treatment with the Er,Cr:YSGG laser effectively and quickly reduced dentin hypersensitivity when compared to a placebo treatment.[23] Furthermore, it was proven that the Er,Cr:YSGG laser demonstrated superior performance in treating dentin hypersensitivity when compared to alternative desensitizing agents.[24] Consequently, we were compelled to select the Er,Cr:YSGG laser as one of the comparators in the current study in order to evaluate its efficacy in treating DH.

Er,Cr:YSGG laser emits light in mid-infrared region at 2.78 nm. The 2.78 nm wavelength Er,Cr:YSGG laser was selected for current experiment, since it is anticipated to be effective in dental applications due to its thermomechanical ablation mechanism and the strong absorption of their wavelengths by water. Favoring to their ability to mitigate numerous shortcomings, such as avoiding thermal harm to the dental pulp and preventing surface damage to dental hard tissues like dentin.[25,26] At high laser powers, Er,Cr:YSGG laser can produce hard tissue ablation and can be used for removing dental caries.[22] Based on the parameters used by Yilmaz and Bayindir; who used the sub-ablative dose (0.25 watts) of Er,Cr:YSGG laser treatment over a three-month period, the laser parameters used in the current study were sub-ablative to avoid dentin damage. As they revealed that the 0.25-watt laser treatment has been proven to be an efficient and enduring method for treating dentin hypersensitivity.[27]

Bioactive glass was our second comparator in treating dentin hypersensitivity, as it has shown great effectiveness in reducing pain associated with dentin hypersensitivity. Bioactive glasses are mainly made of silicon, sodium, calcium, and phosphorus in certain amounts. When these glasses come in contact with biological fluids like saliva, three things occur: (1) they release silanols, (2) they break down, and (3) they create solid particles. This last step is vital for sealing dentinal tubules. An outer layer forms as a result of the glass's release of silica, calcium, and phosphate ions. This layer can physically block dentinal tubules, reducing fluid flow in the dentin.[28-32] In our experiment nano-sized bioactive glass was used since it was suggested that bioactive glass with smaller particle sizes would dissolve at a faster rate due to their greater surface area. As a result, they are more likely to come into contact with surrounding materials.[33] Moreover, Sheng *et al*.; discovered that nano-BG particles were more effective than micro-BG and submicro-BG particles in promoting mineral formation for sealing dentinal tubules[34]

The SEM results of the current study demonstrated how the efficiency of all treatments were measured in comparison to the control group. And most of all, the effectiveness of the nanoBG+laser group. SEM images of nanoBG group showed aggregations BG nanoparticles on the dentin surface, while partially occluded dentinal tubules with the nanoBG paste were seen. These finding were advocated by Lee *et al*.; who found that applying BG paste to previously 17% EDTA treated dentin specimen revealed that the dentin surface was mostly covered in clusters of crystalline-like structures, with uniformly distributed BG particles partially obstructing the dentinal tubules.[6]

The mean diameter of the dentinal tubules in the Er:Cr:YSGG laser group's SEM pictures dropped to 1.924 um from the control group's 3.724 um with signs of dentin melting in form of occlusion plugs obliterating the dentinal tubules. These findings came in parallel with Gholami *et al*.; who reported that applying Er:Cr:YSGG laser with the same parameters of our study (Power= 0.25 W, Frequency = 20 Hz, Wavelength: 2,780 nm Pd = 140 µs, 0% water) to etched dentin specimens revealed that the dentinal tubules were blocked by the melting of the peritubular dentin. By calculating the average diameters of the dentinal tubules, they verified their findings for Er;Cr:YSGG group, that was 1.73 um whereas the mean diameter was 3.52 among the control group.[11]

The results of our investigation showed that the Er:Cr:YSGG laser group was superior to nanoBG group in terms of SEM photomicrographs, dentinal tubule mean diameter, and EDX analysis for calcium and phosphrous content. Similarly, Kamel *et al*., 2021; compared the impact of Er,Cr:YSGG (λ = 2780 nm) laser and 45S5 BG paste on the remineralization of enamel white spot lesions. They confirmed that the Er,Cr:YSGG laser group functioned better than the BG group in remineralizing the enamel white spots.[35] Conversely, Papazisi *et al*.; discovered that BG45S5 completely blocked nearly all dentin tubules (over 99%), while the use of Er,Cr:YSGG laser was also successful in blocking dentin tubules but to a significantly lesser degree (26.8%). This can be attributed to the variation in the method used for preparing the BG, since they underwent pretreatment with sandblasting in wet mode for a duration of 10 seconds. Additionally, their experiment had a longer duration, as the samples were immersed in an artificial saliva solution for a duration of 2 weeks.[36]

The combination of nanoBG with Er;Cr:YSGG laser showed more profound results than using either laser alone or using nanoBG alone, such combination increased dentinal tubules occlusion with lowest mean of dentinal tubules diameter was recorded in nanoBG+laser. In accordance to our results, De Souza Penha *et al*.; demonstrated that within 24 hours of exposing 45S5 BG to Nd:YAG laser irradiation, a layer of fused BG formed on the dentin surface. The results of their EDX investigation provided support for their hypothesis regarding the 45S5 BG layer's capacity that facilitate improved ionic exchanges with the medium and its solubility, thereby allowing for the immediate deposition of calcium and phosphate.[37] Similarly, Kung *et al*.; found that applying both the mesoporous BG therapy and the Er: YAG laser to the dentin specimen may form an occlusion plug on the surface with a 96% occlusion efficiency, in comparison to BG group and ER: YAG group 94% and 64% respectively[38] Our results can be explained by Pereira *et al*.; who proposes that laser irradiation of BG particles can create a strong layer that resists demineralization. This is because the irradiation causes morphological changes along with the presence of carbonate free radicals. In turn, these radicals have the potential to substitute hydroxyl ions and react with phosphate ions, resulting in the formation of a phase that is less soluble. The inclusion of BG would enhance the presence of calcium and phosphate ions.[39] Furthermore, a study conducted by Bilandzic *et al*.; demonstrated that BG ceramics can form a chemical link with bovine enamel when a CO2 laser was utilized. These findings suggest that chemical interactions between dentin and BGs cannot be neglected.[40]

The limitations of this study included the assessment of dentinal tubules occlusion mainly through the evaluation of short-term mineral deposition on the dentin surface. The samples were maintained in an artificial saliva solution for a brief period of time. This enabled inferences to be made solely about the short-term effectiveness of the products employed for the treatment of DH. Another constraint of the current study was the minimum quantity of dentin samples and their absence of acidic challenges.

CONCLUSION

Combination of nano-BG and Er,Cr:YSGG laser were found more effective with superior results, rather than using each modality alone in treating dentin hypersensitivity. Irradiating the specimen with Er,Cr:YSGG laser after applying nano-BG paste gave superior sealing effect on the dentinal tubules with lowest mean of dentinal tubules diameter and highest calcium and phosphorous weight percent.

RECOMMENDATIONS

Further studies are required to investigate the effects of altering the parameters of the Er,Cr:YSGG laser, specifically in terms of power, frequency, and duration as well as greater sample size and longer follow-up periods than the present study. Comparative clinical trials and long-term investigations are necessary to validate the effectiveness of these medications for pain alleviation and dentin calcification.

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Canadian Advisory Board on Dentin Hypersensitivity. Consensus-based recommendations for the diagnosis and management of dentin hypersensitivity. Journal (Canadian Dental Association). 2003; 69(4):221-6. PMID: 12662460
2. Zeola LF, Soares PV, Cunha-Cruz J. Prevalence of dentin hypersensitivity: Systematic review and meta-analysis. Journal of dentistry. 2019; 1(81):1-6. DOI: 10.1016/j.jdent.2018.12.015
3. Arora A, Gupta U, Gupta I. Dentin Hypersentivity: A Literature Review. International Journal of Health Sciences. 2021; 5:63-72. DOI:10.53730/ijhs.v5nS1.5345
4. Douglas-de-Oliveira DW, Vitor GP, Silveira JO, Martins CC, Costa FO, Cota LO. Effect of dentin hypersensitivity treatment on oral health related quality of life—A systematic review and meta-analysis. Journal of Dentistry. 2018; 1;71:1-8 .DOI:10.1016/j.jdent.2017.12.007
5. Rezazadeh F, Dehghanian P, Jafarpour D. Laser effects on the prevention and treatment of dentinal hypersensitivity: a systematic review. Journal of lasers in medical sciences. 2019; 10(1):1. DOI: 10.15171/jlms.2019.01\
6. Lee EM, Borges R, Marchi J, de Paula Eduardo C, Marques MM. Bioactive glass and high-intensity lasers as a promising treatment for dentin hypersensitivity: An in *vitro* study. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2020; 108(3):939-47. DOI:10.1002/jbm.b.34446
7. Yadav RK, Verma UP, Tiwari R. Comparative evaluation of neodymium-doped yttrium aluminum garnet laser with nanocrystalline hydroxyapatite dentifrices and herbal dentifrices in the treatment of dentinal hypersensitivity. National journal of maxillofacial surgery. 2019; 10(1):78. DOI: 10.4103/njms.NJMS_47_18
8. Gholami GA, Fekrazad R, Esmaiel-Nejad A, Kalhori KA. An evaluation of the occluding effects of Er; Cr: YSGG, Nd: YAG, CO2 and diode lasers on dentinal tubules: a scanning electron microscope in *vitro* study. Photomedicine and laser surgery. 2011; 29(2):115-21. DOI: 10.1089/pho.2009.2628
9. Harashima T, Kinoshita JI, Kimura Y, Brugnera Jr A, Zanin F, Pecora JD, Matsumoto K. Morphological comparative study on ablation of dental hard tissues at cavity preparation by Er: YAG and Er, Cr: YSGG lasers. Photomedicine and Laser Therapy. 2005 Feb 1;23(1):52-5. DOI: 10.1089/pho.2005.23.52
10. Ozlem K, Esad GM, Ayse A, Aslihan U. Efficiency of lasers and a desensitizer agent on dentin hypersensitivity treatment: a clinical study. Nigerian journal of clinical practice. 2018 ;21(2):225-30. DOI: 10.4103/njcp.njcp_411_16
11. Liu Y, Gao J, Gao Y, Shuaimei XU, Zhan X, Wu B. In *vitro* study of dentin hypersensitivity treated by 980-nm diode laser. Journal of lasers in medical sciences. 2013 ;4(3):111. PMID: 25606318; PMCID: PMC4295358.
12. Aranha AC, de Paula Eduardo C. Effects of Er: YAG and Er, Cr: YSGG lasers on dentine hypersensitivity. Short-term clinical evaluation. Lasers in medical science. 2012; 27:813-8. DOI: 10.1007/s10103-011-0988-9
13. João-Souza SH, Machado AC, Lopes RM, Zezell DM, Scaramucci T, Aranha AC. Effectiveness and acid/tooth brushing resistance of in-office desensitizing treatments—A hydraulic conductance study. Archives of oral biology. 2018; 96:130-6. DOI:10.1016/j.archoralbio.2018.09.004
14. Zhou Z, Yi Q, Gao Y, Liu L, Liu Q, Zhao Y, Zeng W, Zhou J, Yang Z. Biocompatibility in-*vivo* of poly-L-lactide and bioactive glass composite substitute for internal fracture fixation. Polymers and Polymer Composites. 2011; 19(9):797-802. DOI:10.1177/096739111101900910
15. Zhong Y, Liu J, Li X, Yin W, He T, Hu D, Liao Y, Yao X, Wang Y. Effect of a novel bioactive glass-ceramic on dentinal tubule occlusion: an in *vitro* study. Australian dental journal. 2015; 60(1):96-103. DOI: 10.1111/adj.12241
16. Lu X, Kolzow J, Chen RR, Du J. Effect of solution condition on hydroxyapatite formation in evaluating bioactivity of B2O3 containing 45S5 bioactive glasses, Bioact. Mater. 2019; 4:207–214. DOI:10.1016/j.bioactmat.2019.05.002
17. Taher HM, Haridy MF. Effect of Artificial Saliva, Bioactive Glass and Fluoride Varnish on Micro-hardness and Micro-shear Bond Strength of Demineralized Enamel Surface. Egyptian Dental Journal. 2019; 65(1):837-47. DOI: 10.21608/edj.2019.72872
18. Pourshahidi S, Ebrahimi H, Mansourian A, Mousavi Y, Kharazifard M. Comparison of Er, Cr: YSGG and diode laser effects on dentin hypersensitivity: a split-mouth randomized clinical trial. Clinical oral investigations. 2019; 23:4051-8. DOI: 10.1007/s00784-019-02841-z
19. Vazirizadeh Y, Azizi A, Lawaf S. Comparison of the efficacy of 940-nm diode laser, Gluma, and 5% sodium fluoride varnish in dentinal tubule occlusion. Lasers in Dental Science. 2022; 6(1):63-70. DOI:10.1007/s41547-021-00139-6

20. Kara HB, Cakan U, Yilmaz B, Inan Kurugol P. Efficacy of diode Laser and Gluma on post-preparation sensitivity: A randomized split-mouth clinical study. Journal of esthetic and restorative dentistry. 2016; 28(6):405-11. DOI:10.1111/jerd.12230

21. Aranha AC, de Paula Eduardo C. Effects of Er: YAG and Er, Cr: YSGG lasers on dentine hypersensitivity. Short-term clinical evaluation. Lasers in medical science. 2012; 27:813-8. DOI: 10.1007/s10103-011-0988-9

22. Aranha AC, Pimenta LA, Marchi GM. Clinical evaluation of desensitizing treatments for cervical dentin hypersensitivity. Brazilian oral research. 2009; 23:333-9. DOI:10.1590/S1806-83242009000300018

23. Yilmaz HG, Cengiz E, Kurtulmus-Yilmaz S, Leblebicioglu B. Effectiveness of Er, Cr: YSGG laser on dentine hypersensitivity: a controlled clinical trial. Journal of clinical periodontology. 2011; 38(4):341-6. DOI:10.1111/j.1600-051X.2010.01694.x

24. Chaudhry S, Yadav S, Talwar S, Verma M. A comparative evaluation of erbium, chromium: Yttrium-Scandium-Gallium-Garnet laser with three other desensitizing agents for the management of dentinal hypersensitivity: a hospital-based study. Journal of Dental Lasers. 2018; 12(1):18. DOI: 10.4103/jdl.jdl_5_18

25. Braun A, Jepsen S, Deimling D, Ratka-Krüger P. Subjective intensity of pain during supportive periodontal treatment using a sonic scaler or an Er: YAG laser. Journal of clinical periodontology. 2010; 37(4):340-5. DOI:10.1111/j.1600-051X.2010.01536.x

26. Al-Shammari AM, Salman AM, Al-janabi A. Safe and efficient dental cavity preparation by applying a gradient-in-power approach from Er, Cr: YSGG laser: an in-*vitro* study. Optics Continuum. 2023; 2(4):917-32. DOI:10.1364/OPTCON.488099

27. Yilmaz HG, Bayindir H. Clinical and scanning electron microscopy evaluation of the Er, Cr: YSGG laser therapy for treating dentine hypersensitivity: short-term, randomised, controlled study. Journal of oral rehabilitation. 2014; 41(5):392-8. DOI:10.1111/joor.12156

28. Davis HB, Gwinner F, Mitchell JC, Ferracane JL. Ion release from, and fluoride recharge of a composite with a fluoride-containing bioactive glass. Dental Materials. 2014; 30(10):1187-94. DOI:10.1016/j.dental.2014.07.012

29. Mitchell JC, Musanje L, Ferracane JL. Biomimetic dentin desensitizer based on nano-structured bioactive glass. Dental Materials. 2011; 27(4):386-93. DOI:10.1016/j.dental.2010.11.019

30. Behzadi S, Mohammadi Y, Rezaei-Soufi L, Farmany A. Occlusion effects of bioactive glass and hydroxyapatite on dentinal tubules: a systematic review. Clinical Oral Investigations. 2022; 26(10):6061-78. DOI:10.1007/s00784-022-04639-y

31. Da Cruz LP, Hill RG, Chen X, Gillam DG. Dentine tubule occlusion by novel bioactive glass-based toothpastes. International Journal of Dentistry. 2018; 2018:1-10. DOI:10.1155/2018/5701638

32. Bologa E, Stoleriu S, Nica I, Tărăboanță I, Georgescu A, Matei RI, Andrian S. The Effect of Three Desensitizing Toothpastes on Dentinal Tubules Occlusion and on Dentin Hardness. Biomedicines. 2023;11(9):2464. DOI:10.3390/biomedicines11092464

33. Curtis AR, West NX, Su B. Synthesis of nanobioglass and formation of apatite rods to occlude exposed dentine tubules and eliminate hypersensitivity. Acta biomaterialia. 2010; 6(9):3740-6. DOI:10.1016/j.actbio.2010.02.045

34. Sheng XY, Gong WY, Hu Q, Chen XF, Dong YM. Mineral formation on dentin induced by nano-bioactive glass. Chinese Chemical Letters. 2016; 27(9):1509-14. DOI: 10.1016/j.cclet.2016.03.030

35. Kamel E, Hassouna DM, Geith ME. In *Vitro* Study To Evaluate The Effect Of 45S5 Bioglass Paste And Er, Cr: YSGG 2780 nm Laser On Re-Mineralization Of Enamel White Spot Lesions (Energy Dispersive X-ray Analysis and Stereomicroscopic assessments). Egyptian Dental Journal. 2021; 67:301-14. DOI:10.21608/EDJ.2020.42112.1250

36. Papazisi N, Dionysopoulos D, Naka O, Strakas D, Davidopoulou S, Tolidis K. Efficiency of various tubular occlusion agents in human dentin after in-office tooth bleaching. Journal of Functional Biomaterials. 2023; 14(8):430. DOI: 10.3390/jfb14080430

37. De Souza Penha KJ, de Oliveira Roma FR, Torres CR, Bauer JR, Firoozmand LM. Effect of bioactive glasses and neodymium: yttrium-aluminum-garnet laser on dentin permeability. Journal of Conservative Dentistry: JCD. 2020; 23(6):583. DOI: 10.4103/JCD.JCD_453_20

38. Kung JC, Wang WH, Chiang YC, Yang-Wang YT, Wang YC, Chen WC, Shih CJ. The antibacterial and remineralization effect of silver-containing mesoporous bioactive glass sealing and Er-yag laser on dentinal tubules treated in a Streptococcus mutans cultivated environment. Pharmaceuticals. 2021; 14(11):1124. DOI:10.3390/ph14111124

39. Pereira DL, Freitas AZ, Bachmann L, Benetti C, Zezell DM, Ana PA. Variation on molecular structure, crystallinity, and optical properties of dentin due to Nd: YAG laser and fluoride aimed at tooth erosion prevention. International Journal of Molecular Sciences. 2018; 19(2):433. DOI:10.3390/ijms19020433

40. Bilandžić MD, Wollgarten S, Stollenwerk J, Poprawe R, Esteves-Oliveira M, Fischer H. Glass-ceramic coating material for the CO2 laser based sintering of thin films as caries and erosion protection. Dental Materials. 2017; 33(9):995-1003. DOI:10.1016/j.dental.2017.06.008

الملخص العربى

تأثير الإربيوم والكروم: ليزر إيتريوم سكانديوم جاليوم جارنت (ER Cr: YSGG) ومعجون الجسيمات النانوية الزجاجية النشطة بيولوجيًا (nanoBG) على إغلاق الأنابيب العاجية.(دراسه مختبريه)

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المقدمه: فرط حساسية العاج هي قضية أسنان مألوفة ومؤلمة تتميز بألم قصيرعندما يتفاعل العاج المكشوف مع محفزات مختلفة. تم اختبار الزجاج النشط بيولوجيًا وأنواع متعددة من الليزر في علاج فرط حساسية العاج ومع ذلك، لم يسبق ان يتم دمجمهم معًا في إغلاق أنابيب العاج المكشوف.
الهدف من البحث: تركز الدراسة الحالية على تقييم تأثير الإربيوم والكروم: ليزر إيتريوم سكانديوم جاليوم جارنت (ER Cr: YSGG) ومعجون الجسيمات النانوية الزجاجية النشطة بيولوجيًا (nanoBG) إما بمفردها أو بالاقتران مع تسلسلات مختلفة في التطبيق؛ على إغلاق الأنابيب العاجية.
مواد وطرق البحث: تم استخدام أربعون أسنانًا من الضواحك المخلوعة لهذه الدراسة. تم توزيعها بالتساوي على مجموعة تحكم و ٤ مجموعات تجريبية. مجموعة NanoBG: تعالجت بمعجون nanoBG فقط، مجموعة ليزر Cr: YSGG:Er: تمت معالجته بالإشعاع بالليزر وحده، nanoBG Cr: YSGG laser+: Er : تمت معالجته بمعجون nanoBG بعد الأشعاع بالليزر. مجموعة الليزر Cr: YSGG: nanoBG+ Er: يتم معالجتها بمعجون nanoBG قبل الإشعاع بالليزر. تم تقييم عينات العاج عن طريق مسح المجهر الإلكتروني (SEM)، مع تحليل لاحق لمتوسط قطر أنابيب العاج، وتحليل الكالسيوم والفوسفور عن طريق تحليل مطيافية الأشعة السينية المشتتة للطاقة (EDX).
النتائج: أظهرت مجموعة الليزر NanoBG + ErCr: YSGG ، تحسنًا كبيرًا في إغلاق أنابيب العاج مقارنة بالمجموعات الأخرى من خلال تصوير SEM. تم تأكيد النتائج من خلال تحليل EDX الذي كشف عن أعلى وزن للكالسيوم والفوسفور٪، بالإضافة إلى تسجيل أقل قطر متوسط لأنابيب العاج بين المجموعات ($p < ٠٫٠٥$).
خلاصة البحث: يوفر تطبيق nanoBG و Cr: YSGG laser:Er بمفردهم الى إغلاقًا مرضيًا لأنابيب العاج. على الرغم من ان دمجهم معا ادى الي أكثر كفاءة مع نتائج فائقة، بدلاً من استخدام كل طريقة وحدها.