Journal of Lasers in Medical Sciences

J Lasers Med Sci 2023;14:e56

Original Article

http://journals.sbmu.ac.ir/jlms

doi 10.34172/jlms.2023.56

Evaluation of the Effect of NovaMin and Er,Cr:YSGG Laser on Remineralization of Erosive Lesions of Primary Enamel Teeth: An In Vitro Study

Yoones Sadabadi[1], **Majid Mehran**[1], **Mohammad Bagher Rezvani**[2], **Mohammad Asnaashari**[3], **Roza Haghgoo**[1*]

[1]Department of Pediatric Dentistry, School of Dentistry, Shahed University, Tehran, Iran
[2]Department of Operative Dentistry, School of Dentistry, Shahed University, Tehran, Iran
[3]Laser Application in Medical Sciences Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

***Correspondence to**
Roza Haghgoo,
Email: haghgoodent@yahoo.com

Received: August 16, 2023
Accepted: October 4, 2023
Published online: November 13, 2023

Abstract

Introduction: The purpose of this in vitro study is to ascertain how NovaMin and Er,Cr:YSGG laser radiation affect the remineralization of primary tooth enamel lesions.

Methods: 40 main teeth served as the study's sample size. These teeth were allocated into five groups at random. The first group served as a negative control (artificial saliva); the second group served as a positive control (APF gel 1.23%); the third group NovaMin, the fourth group Er,Cr:YSGG laser, the fifth group Er,Cr:YSGG laser and finally, the application of NovaMin. For the purpose of measuring microhardness, all samples were submitted to the dental materials laboratory three times.

Results: The collected data were compared using the SPSS 28 program between the baseline measurement, after demineralization, and after remineralization. The data were analyzed using ANCOVA and Bonferroni tests. All groups demonstrated a considerable increase in microhardness as compared to the negative control group ($P<0.05$). With the exception of the third and fourth groups, there was no discernible difference in the rise in microhardness between the other groups. The third and fourth groups were compared, and the results revealed that NovaMin had a greater impact than laser therapy alone ($P=0.023$). Scanning electron microscopy (SEM) analysis backed up the findings.

Conclusion: In comparison to using the Er,Cr:YSGG laser alone, using NovaMin alone can speed up the remineralization of erosion lesions on the surface of primary teeth.

Keywords: Primary teeth; Enamel erosion; Remineralization; Er,Cr: YSGG Laser.

Introduction

The potential for tooth enamel remineralization has been one of the key issues in pediatric dentistry since, at a cheap cost, it can prevent primary teeth from decaying and, as a result, discomfort, infection, and tooth loss. Consuming beverages and foods that have the potential to cause erosion, having less saliva produced, and having irregularities in the development of the tooth enamel are some of the most frequent risk factors for dental erosion in children. Due to the primary tooth's poor mineralization, higher water content, and enhanced permeability in comparison to permanent teeth, dental erosion advances quickly in these teeth. Dental erosion starts when a solution that has a pH lower than the critical pH of tooth enamel (5.5) comes in contact with the surface of the tooth, which is then attacked by hydrogen cations produced by acidic substances. As a result, the hard tissues of the tooth are lost, and its hardness is decreased.[1] One of its significant negative effects is sensitization, which also alters the way the teeth look. As a physical defense against acid challenges and a source of calcium and fluoride ions, which are produced when the pH lowers, fluoride varnishes are the usual therapy. They have the capacity to stick to the enamel surface and build a coating of calcium fluoride on the enamel surface.[1]

Fluoride has a modest power to stop bacterial growth and a capacity to induce remineralization.[2] Because the calcium fluoride layer that is created by eating acidic substances gradually dissolves, fluoride also has a limited impact on preventing demineralization. Finding a reliable way to strengthen tooth resilience and hence enhance oral health is required.[3]

A unique kind of biomaterial called bioactive glass has the power to repair dentin and enamel defects, as well as rebuilding the bone.[4,5] An artificial substance called NovaMin (Sensodyne, a GSK firm), which binds to the surface of teeth constantly and quickly releases crystalline deposits of natural hydroxyl carbonate, is made of

Please cite this article as follows: Sadabadi Y, Mehran M, Rezvani MB, Asnaashari M, Haghgoo R. Evaluation of the effect of NovaMin and Er,Cr:YSGG laser on remineralization of erosive lesions of primary enamel teeth: an in vitro study. *J Lasers Med Sci*. 2023;14:e56. doi:10.34172/jlms.2023.56.

calcium, sodium, phosphorus, and silica agents. When exposed to moisture, each of the tiny particles in NovaMin releases millions of mineral ions, which ultimately leads to the development of a solid hydroxyapatite layer on the surface of enamel and dentin. Due to this power, tooth sensitivity is reduced and damage is cured.[6] When this substance is exposed to moisture, sodium ions begin to exchange with hydrogen ions, and the quick release of ions causes calcium and phosphate ions to be released from the structure of the molecule. These reactions take place in a matter of seconds, and the release of calcium and phosphate ions keeps on as long as the particles are near a moist environment. At this level, the release of salt causes a brief rise in local pH.[7]

The calcium and phosphate ions in the NovaMin structure and the calcium and phosphorus in the saliva combine to produce a coating of calcium phosphate on the surface of the teeth when the local pH rises. This layer changes into hydroxycarbonate apatite, which is physically and chemically identical to biological apatite, as calcium and phosphorus continue to be deposited on it.[6,7] The sodium and calcium released by NovaMin may alter the osmotic conditions in the oral cavity and may induce bacterial cell dehydration, which can reduce caries-causing microorganisms such as mutans streptococci.[8]

A High-power laser is another therapeutic technique that alters the tooth surface and causes hydroxyapatite crystals to disintegrate at a less acidic pH.[9] Our understanding of the utilization of hydroxyapatite crystals is limited, and there is contradicting information available. For its anti-erogenous qualities, laser treatment with newer remineralizing agents is available, notably in primary tooth enamel.[1] Erbium lasers come in two popular varieties, Er: YAG and Er,Cr:YSGG, both of which are used often in dentistry and share many similarities.[10] The Er,Cr:YSGG laser has been demonstrated to be superior to Er: YAG due to better hydroxyapatite absorption, deeper penetration, and less erosion impact.[11]

The objective of this in vitro study is to ascertain how NovaMin and Er,Cr:YSGG laser radiation affect the remineralization of primary tooth enamel lesions.

Materials and Methods

The current in vitro study has an ethical code registered at Shahed University of Tehran with the registration number (IR.SHAHED.REC.1400.079). Forty primary teeth from the mandibular and maxillary jaws were used in this investigation. Using SPSS version 25 software and data from prior investigations, the number of samples was calculated.

The formula for n is (Z/2+Z)2 * (p1(1-p1)+p2(1-p2)) / (p1-p2).2

Which P, the power of the beta-1test, and alpha-1, the significant level, represent the proportion of success in each group, respectively. The number of samples is 40 when the power is 80%, and the significance level is 95% for success rates between 85% and 100%. Primary teeth having at least one healthy surface and no cracks or fractures met the inclusion criteria, whereas the exclusion criteria were as follows: Primary teeth had fractures in the communication, hypoplastic lesions, and caries on all surfaces.

Observation and experimentation were the data collection methods. First, self-curing acrylic was used to attach the teeth (Integra Incorporated Dental Group, Turkey). The enamel surface was uniformly polished with silicon carbide (2000, 1000, and 600) for the samples (Matador Wasser Quick, Germany). Additionally, an area of 4×4 mm was left untouched in the middle, and the region surrounding the exposure area was coated with an acid-resistant varnish. Vickers Microhardness Test (Zwick, U.K.) was used to determine the initial microhardness of all samples. Three locations (indents) were subjected to a force of 100 g for 10 seconds in this direction, perpendicular to the primary tooth enamel. [1,12]

In the second step, the samples were subjected to a demineralizing solution containing (2.2 mM calcium chloride, 2.2 mM sodium phosphate, 0.05 mM acetic acid, and 1 mM potassium hydroxide) for 96 hours at a temperature of 37 °C in order to produce fake erosive lesions with a pH of 4.2. The microhardness of all samples was then assessed once more. The samples were then split into 5 groups, 3 experimental groups and 2 control groups, using randomization. There were 8 samples in each of the experimental and control groups.

The samples in the first group (the negative control) were left in synthetic saliva for 14 days. Gastric leucine, 0.381 g/L sodium chloride, 0.213 g/L calcium chloride, 0.738 g/L potassium hydrogen phosphate, and 1.114 g/L potassium chloride are all components of artificial saliva.

The samples in the second group (the positive control) were exposed to an APF 1.23% gel (Iran's Nik Darman APF Fluoride Gel) for one minute each day for 14 days. In the third group (NovaMin), the samples were given Sensodyne toothpaste, which contains NovaMin twice daily for two minutes each, for a period of fourteen days. Ingredients in toothpaste made by the GSK firm in the UK include Glycerin PEG-8 hydrated silica calcium sodium phosphosilicate (NovaMin) cocamidopropyl betaine sodium methyl cocoyl taurate fragrance titanium dioxide carbomer sodium saccharin (which is manufactured by GSK company, UK). The samples in the fourth group (Er,Cr:YSGG laser) were subjected to the laser with the following settings: power 0.75 W, frequency 20 Hz, 60% water, 40% air, and pulse duration 140 microseconds (Biolase Waterlase iPlus Technology, Inc., USA), tip: mz-8 (Biolase, Inc., USA) and 15 seconds of irradiation at a distance of 1.1–1.5 mm from the tooth surface.

The samples in the fifth group (Er,Cr:YSGG laser with NovaMin) were treated with NovaMin twice daily for two minutes each for 14 days after being initially exposed to Er,Cr:YSGG laser radiation with the aforementioned settings. The microhardness of all samples was assessed once more after 21 days (Table 1). After the intervention and up to the intervention, all samples were put in distilled water. After the remineralization stage, one sample with sound enamel, one sample with eroded enamel, and one sample from each group were randomly chosen and examined under a scanning electron microscope (SEM) to assess surface alterations. The morphological differences between the samples were determined and compared using a scanning electron microscope (FESEM equipment, ZEISS, Germany - Sigma VP type). Images were taken at magnifications of 1000, 3000, and 10 000. SEM had an acceleration voltage of 10 kV.

The significance level for the ANCOVA and Bonferroni statistical tests, which were used to examine the microhardness test results, was set at 0.05.

Results

Before demineralization, the microhardness of the groups was assessed using a Vickers Pyramid Number (HV) which was 309 to 372 hard, the microhardness after demineralization with an HV of 162 to 192, and the microhardness after remineralization with an HV of 169 to 259. Additionally, the groups' average microhardness during the fundamental measurement periods, during demineralization and during remineralization was 338 hard HV, and 175 hard HV, and 228 hard HV respectively (Table 2).

In terms of baseline, demineralization, and remineralization durations, groups 2 (APF 1.23%), 3 (Laser), and 5 (Laser + NovaMin), respectively, had the greatest average among the groups. Additionally, the synthetic saliva and NovaMin groups had the lowest average microhardness among the groups during the basic, demineralization, and remineralization phases (Table 2 and Figure 1).

An analysis of covariance (ANCOVA) analysis of the covariance test was used to examine the data. In the model, two measurements—base and after demineralization—were taken into account and modified as factors. The findings of the analysis revealed that while there was no significant difference between the groups before remineralization, there was (P value > 0.001) a significant difference between them thereafter (Table 3).

There was a significant difference in microhardness between the groups at the time of remineralization ($P < 0.05$) (Table 3). Therefore, Bonferroni's pairwise comparison was used, as seen in the table, to identify the area of difference between the groups following the treatment (Table 4).

The hydroxyapatite structures in demineralized dental enamel are rough and etched, according to a scan of the SEM in eroded tooth enamel. As seen in Figure 2, laser light causes melting to occur. It was also noted that after melting, the enamel crystals recrystallize to produce larger and more crystals. Comparatively speaking to other groups, the enamel crystal structure is more uniform in the NovaMin group.

When we compared the various groups to the negative control group, it was easy to see the differences in the surface structure change (in the form of remineralization of hydroxyapatite crystals), but when we compared the various groups, only the NovaMin group had more surface uniformity. It can be argued that there has been a significant increase in surface microhardness when compared to the positive control group (Figures 2 and 3).

Discussion

This study was carried out with the intention of "investigating the effect of NovaMin‌ and Er, Cr; YSGG laser on the resistance and remineralization of erosive lesions of primary teeth" due to the issues associated with dental erosion. This study's demineralized solution, which was used to produce erosive waste, has acidity similar to 4.2 pH, which is lower than the critical pH for enamel (5.5). As a result, the hydroxyapatite crystals of enamel were broken down, which eventually decreased tooth microhardness. According to the findings of the current study, the use of toothpaste containing the NovaMin, Er,Cr:YSGG laser and their concomitant usage has a substantial impact on the remineralization of primary tooth enamel erogenous lesions. Enamel

Table 1 Frequency Distribution of Research Samples According to Individual Factor

Group	Sample Size (n = 40)	Explanation
Saliva	8	The samples were placed in artificial saliva at 37°C. The composition of artificial saliva was gastric leucine (2.2 g/L), sodium chloride (0.381 g/L), calcium chloride (0.213 g/L), potassium hydrogen phosphate (0.738 g/L), and chloride Potassium (1.114 g/L).
APF1.23%	8	The samples were exposed to 1.23% APF daily for 1 minute for 14 days.
NovaMin	8	The samples were exposed to toothpaste containing NovaMin twice a day for 2 minutes for 14 days.
Er,Cr:YSGG laser	8	The samples were irradiated with an Er,Cr:YSGG laser with a power of 0.75 W, a frequency of 20 Hz, 60% water, 40% air, and a pulse duration of 60s.
Er,Cr:YSGG laser & NovaMin	8	The samples were first irradiated for 15 seconds with an Er,Cr:YSGG laser with a power of 0.75 watts, a frequency of 20 Hz, 60% water, 40% air, and a pulse duration of 140 microseconds, and then with toothpaste containing NovaMin twice a day. They were treated for 2 minutes for 14 days.

Table 2. Frequency distribution of the microhardness values of the groups

Group		Sample Size	Base MH	DEM MH	REM MH
1	Saliva	8	309.637	174.162	169.350
2	APF 1.23%	8	372.500	183.275	257.287
3	Er,Cr:YSGG LASER	8	339.987	162.038	213.394
4	NovaMin	8	326.494	164.456	259.719
5	Er,Cr:YSGG Laser & NowaMin	8	343.994	192.225	244.800
Total		40	338.522	175.231	228.910

Data were presented using numbers and averages.
MH, Microhardness; DEM, Demineralization; REM, Remineralization.

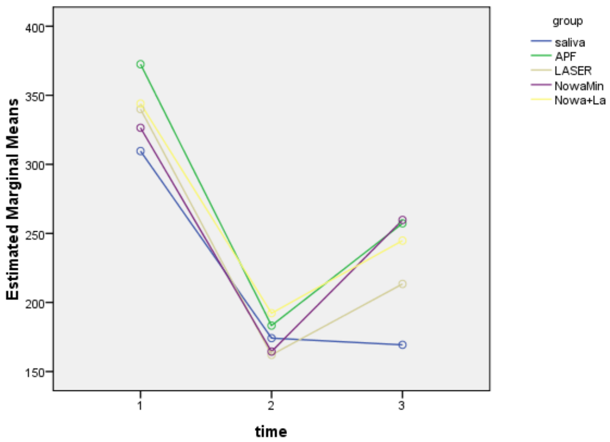

Figure 1. Comparison of the Mean Microhardness of the Groups Based on the Base, Demineralization and Remineralization Times. 1: base microhardness 2: demineralization microhardness 3: remineralization microhardness

Table 3. Investigating and Comparing the Effect of Treatments on the Amount of Microhardness During the Study

Source	Type III Sum of Squares	Df	Mean Square	F	*P* value
Corrected Model	62653.571[a]	6	10442.262	13.190	0.000
Intercept	20920.733	1	20920.733	26.425	0.000
Base	736.494	1	736.494	0.930	0.342
After Demineralization	11768.703	1	11768.703	14.865	0.001
Group	39762.061	4	9940.515	12.556	0.000
Error	26125.740	33	791.689		
Total	2184770.835	40			
Corrected Total	88779.311	39			

[a] R Squared = 0.706 (adjusted R squared = 0.652).

Table 4. Pair-group Comparison*

Groups		Mean difference of groups	Standard error	Confidence interval for the difference 95%	*P* value
C-	C+	-79.828	15.012	-124.988 to -34.667	0.000
	N	-92.011	14.193	-134.708 to -49.315	0.000
	L	-45.320	14.406	-88.565 to -1.983	0.035
	N+L	-66.908	14.353	-110.084 to -23.731	0.000
C+	N	-12.183	14.562	-55.989to 31.622	1.000
	L	34.508	14.338	-8.624 to 77.640	0.219
	N+L	12.920	14.344	-30.229 to 56.069	1.000
N	L	46.691	14.124	-4.204 to 89.179	0.023
	N+L	25.103	14.249	-17.762 to 67.969	0.874
L	N+L	-21.588	14.266	-64.504 to 21.328	1.000

C-: artificial saliva; C+: APF 1.23%; N: NovaMin; L: Er,Cr:YSGG Laser
*Bonferroni test.
It is estimated based on marginal averages
The mean difference is significant at the 0.05 level.

structures may become physically connected as a result of laser radiation. Enamel crystals join and re-crystallize as a result of melting, which decreases the permeability and solubility of enamel. It is possible that changes in the crystallography of enamel, brought on by the heat produced by the laser, are to blame for the decrease in the solubility of enamel. These changes also result in an increase in crystallinity and the formation of tricalcium phosphate, tetra calcium phosphate, and hydroxyl ions, which increases enamel resistance to acidic solutions and decreases ion emission and demineralization. This is accomplished by raising the temperature of enamel to 400 degrees Celsius, a temperature that may be achieved using the Er,Cr:YSGG laser.[1]

For the way that lasers work, two ideas have been put forth. The enhanced buildup of calcium, phosphate, and fluoride ions in the laser-created porosity and fissures is explained by the first explanation. The second hypothesis postulates that the heat produced by the laser causes fluoride to enter the crystals of hydroxyapatite and fluorapatite. In the first hypothesis, there is a weak link formed between the ions and the tooth structure, but in the second theory, there is a strong bond. The rate of mineralization also rises as a result of the release of water, organic compounds, and carbonate ions from the hydroxyapatite structure brought on by the heat production of the area. In aqueous and hydroxyapatite tissues, the Er,Cr:YSGG laser (wavelength 2780 nm) has the highest absorption rates and Hydroxyapatite crystals in enamel, raises the possibility of remineralization.[13]

The Er,Cr:YSGG laser has been found to greatly alter the remineralization of enamel lesions, according to the findings of the current investigation. However, the kind of primary and permanent teeth used in our study differs from Kumar and colleagues' work.[14] In Elwardani and colleagues' study, a different laser tip (MGG6) was used twice daily, but both studies found that the usage of the Er,Cr:YSGG laser greatly enhanced the remineralization of primary tooth enamel.[11]

According to the research by Khamverdi et al and Chang et al, CO2 laser radiation is efficient in preventing dental enamel demineralization and Chang points

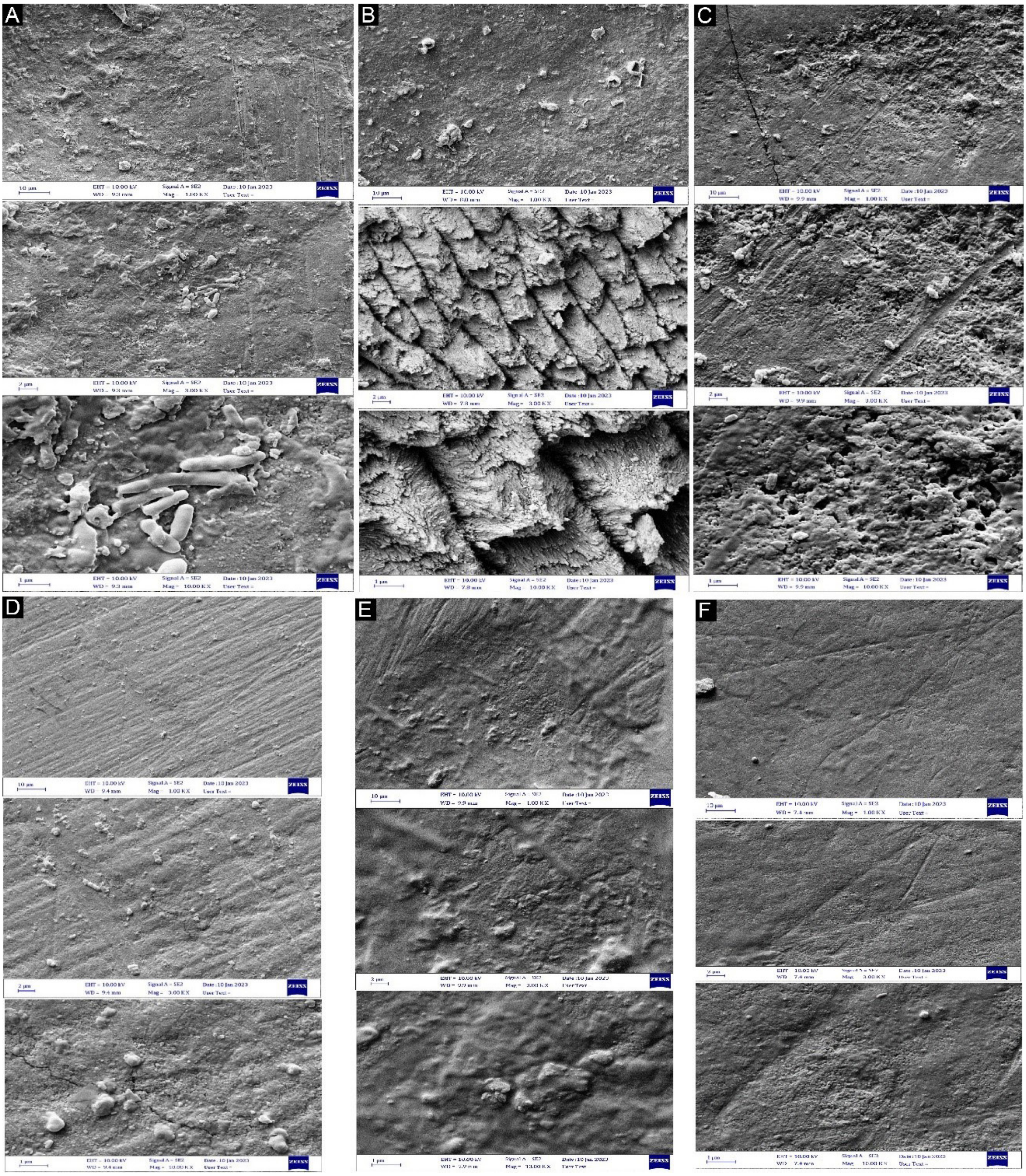

Figure 2. A Basic electron scan images; B Electron scanning images after demineralization; C Electron scan images of saliva; D APF electron scan images; E Laser electron scan images; F NovaMin electron scan images

out the preventive use of the CO2 laser. However, the current study used a different kind of laser and involved a therapeutic procedure.[15,16] In order to validate the impact of the Er,Cr:YSGG laser on raising the microhardness of primary eroded enamel, Yilmaz and colleagues' work is identical to the current investigation, with the exception that our study employed a higher power laser (0.75 W) than Yilmaz and colleagues' study.[1]

According to the research by Molaasadollah,[8,10] the Er: YAG laser cannot prevent erosion in permanent and primary tooth enamel during the erogenous process when used in conjunction with fluoride application; no synergistic effect was found between CPP-ACP and diode laser and CO2; these two studies were not in agreement with the present study; the cause of this discrepancy may be the type of laser used and the different fluoride-

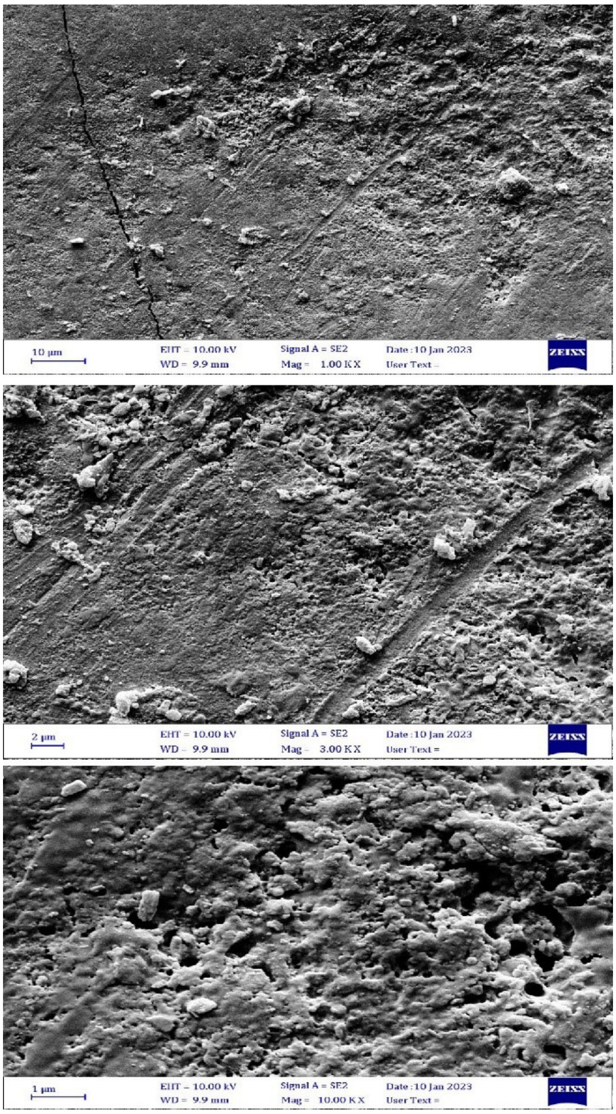

Figure 3. Laser and NovaMin Electron Scan Images

containing products used. Although there was no significant difference between the research groups, the current study suggests that the simultaneous application of the Er,Cr:YSGG laser and NovaMin promotes the remineralization of erogenous lesions.[8]

According to Khamverdi and colleagues' research, mineral enamel regeneration may be possible when casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) is applied along with CO2 laser radiation.[15] Elwardani et al also came to the conclusion that the remineralization of tooth enamel increased significantly regardless of the sequence used in the combination of the Er,Cr:YSGG laser and the remineralizing agent, which is the difference between their study and the present study in the remineralizing substance used.[11]

Researchers Soltanimehr et al,[8] Khamverdi et al,[15] Elwardani et al,[11] noted the growing impact of CPP-ACP on the microhardness of the dental enamel surface in their investigations. With the exception of the fact that NovaMin material was employed in the current investigation, it illustrates the microhardness of the tooth enamel surface. Additionally, the current investigation found that the usage of nanohydroxyapatite and APF in the experiments by Haghgoo et al,[17] Kumar et al,[14] and Chang et al[16] boosted the microhardness of the enamel surface. This discrepancy between the Er,Cr:YSGG laser and NovaMin was found in the current investigation.[8,10,11]

According to Taneja and colleagues' research, the capacity of NovaMin to remineralize teeth is statistically different from other kinds of toothpaste ($P > 0.001$) for DIAGNOdent.[18] We used an electron microscope in our study, while Diagnodent was used in this study. In Joshi and colleagues' study, the increase of the NovaMin group in surface microhardness had a great impact in comparison to the other study groups.[7,19] These investigations, which were similar to ours in that they compared toothpaste containing NovaMin to laser treatment in the present study, demonstrated an increase in the microhardness of the tooth enamel surface in enamel lesions.[19]

According to Manchery and colleagues' study, Nanohydroxyapatite outperforms NovaMin in terms of effectiveness in repairing fake caries lesions.[4] The kind of enamel lesions and the comparison of NovaMin with other materials are where these studies and the current investigation diverge. Of course, the demineralization of the surface is caused by enamel lesions that impact the enamel surface and is comparable in nature to the rise in the microhardness of the tooth surface in the present study. These findings suggest that NovaMin can be used to accelerate the remineralization of erosive lesions in primary tooth enamel.[4]

In the present study, the samples were first exposed to Er,Cr:YSGG laser radiation before NovaMin was applied, which was in agreement with Chang et al[16] and Subramaniam and colleagues'[20] study and in contrast to Kumar and colleagues' study.[14] According to the current study, remineralization increased when NovaMin was administered after laser treatment, albeit obviously not much more than in the other groups. The present study did not address the difference in order, in contrast to Kumar and colleagues' work,[14] which stresses the significance of the order and recommends using fluoride before the laser. Of course, Elwardani and colleagues'[11] analysis indicates that the order has no bearing on mineralization, and this is supported by the fact that mineralization is rising. The composition and arrangement of hydroxyapatite crystals are not sufficiently and positively altered. However, the ideal remineralization of dental enamel is no longer achievable when considerably greater powers are used since they alter and destroy hydroxyapatite crystals in an irreversible manner. Furthermore, because the present study focused on the intervention in primary teeth, other studies that used permanent teeth may have produced results that differ from those of this study. Permanent teeth have more components of their mineral structure made up of hydroxyapatite, which can naturally affect the likelihood of tooth remineralization.[8]

According to the research by Kumar et al and Yilmaz et al, the surface morphology of primary tooth enamel shows a structural shift that increases the quantity of microhardness. This is supported by scanning electron microscopy findings.[1,14,21]

All areas exposed to laser radiation showed the existence of significant unevenness, and it is clear that the enamel surface of primary teeth has melted and re-crystallized. Existing surface coatings may serve as a reservoir of inorganic phases during a caries attack, increasing microhardness and increasing resistance to decay, according to Kumar and colleagues'[14] studies. There was a significant effect of NovaMin on the microhardness of primary tooth enamel compared to the positive control group, despite the comparison of different groups. As a result, although there is no significant difference when compared to the other groups, it can be argued that the reason for the significant difference in the microhardness of the NovaMin group compared to the laser group is that it creates a more homogeneous surface that increases the microhardness in the remineralization process. This can be attributed to the roughness of the surface produced by the laser.

Conclusion

According to the results of this study, the Er,Cr:YSGG laser and NovaMin toothpaste, which is similar to APF 1.23% gel, can improve the mineralization of erosion lesions of primary tooth enamel, and due to the limitations of fluoride, they can be used to repair erogenous lesions of primary teeth. When comparing the two, NovaMin significantly increased microhardness compared to the use of the Er,Cr:YSGG laser alone.

Authors' Contribution

Conceptualization: Yoones Sadabadi.
Data curation: Yoones Sadabadi, Mohammad Asnaashari.
Formal analysis: Yoones Sadabadi Roza Haghgoo.
Funding acquisition: Yoones Sadabadi.
Investigation: Yoones Sadabadi, Roza Haghgoo.
Methodology: Mohammad Bagher Rezvani.
Project administration: Yoones Sadabadi.
Resources: Majid Mehran.
Software: Roza Haghgoo.
Supervision: Roza Haghgoo, Yoones Sadabadi.
Validation: Mohammad Bagher Rezvani.
Visualization: Majid Mehran.
Writing–original draft: Yoones Sadabadi.
Writing–review & editing: Yoones Sadabadi.

Competing Interests

There is not any conflict of interest.

Ethical Approval

This research was approved by the research ethics committee of Shahed University of Tehran (IR.SHAHED.REC.1400.079) and there were not any ethical considerations.

References

1. Yilmaz N, Baltaci E, Baygin O, Tüzüner T, Ozkaya S, Canakci A. 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. 2020;35(7):1607-20. doi: 10.1007/s10103-020-03015-0.
2. Fekrazad R, Najafi A, Mahfar R, Namdari M, Azarsina M. Comparison of enamel remineralization potential after application of titanium tetra fluoride and carbon dioxide laser. Laser Ther. 2017;26(2):113-9. doi: 10.5978/islsm.17-OR-9.
3. Chinelatti MA, Tirapelli C, Corona SAM, Jasinevicius RG, Peitl O, Zanotto ED, et al. Effect of a bioactive glass ceramic on the control of enamel and dentin erosion lesions. Braz Dent J. 2017;28(4):489-97. doi: 10.1590/0103-6440201601524.
4. Manchery N, John J, Nagappan N, Subbiah GK, Premnath P. Remineralization potential of dentifrice containing nanohydroxyapatite on artificial carious lesions of enamel: a comparative in vitro study. Dent Res J (Isfahan). 2019;16(5):310-7.
5. Alafifi A, Yassen AA, Hassanein OE. Effectiveness of polyacrylic acid-bioactive glass air abrasion preconditioning with NovaMin remineralization on the microhardness of incipient enamel-like lesion. J Conserv Dent. 2019;22(6):548-53. doi: 10.4103/jcd.jcd_195_19.
6. Vahid Golpayegani M, Sohrabi A, Biria M, Ansari G. Remineralization effect of topical NovaMin versus sodium fluoride (1.1%) on caries-like lesions in permanent teeth. J Dent (Tehran). 2012;9(1):68-75.
7. Joshi S, Gowda AS, Joshi C. Comparative evaluation of NovaMin desensitizer and Gluma desensitizer on dentinal tubule occlusion: a scanning electron microscopic study. J Periodontal Implant Sci. 2013;43(6):269-75. doi: 10.5051/jpis.2013.43.6.269.
8. Soltanimehr E, Bahrampour E, Yousefvand Z. Efficacy of diode and CO2 lasers along with calcium and fluoride-containing compounds for the remineralization of primary teeth. BMC Oral Health. 2019;19(1):121. doi: 10.1186/s12903-019-0813-6.
9. Apel C, Meister J, Schmitt N, Gräber HG, Gutknecht N. Calcium solubility of dental enamel following sub-ablative Er:YAG and Er:YSGG laser irradiation in vitro. Lasers Surg Med. 2002;30(5):337-41. doi: 10.1002/lsm.10058.
10. Molaasadollah F, Asnaashari M, Mashhadi Abbas F, Jafary M. In vitro comparison of fluoride gel alone and in combination with Er,Cr:YSGG laser on reducing white spot lesions in primary teeth. J Lasers Med Sci. 2017;8(4):160-5. doi: 10.15171/jlms.2017.29.
11. Elwardani GE, Harhash TAH, Zaky AA. Effect of Er,Cr:YSGG on remineralization using CPP - ACPF (MI - Paste Plus) after enamel erosion caused by carbonated soft drink in primary teeth: in-vitro study. Open Access Maced J Med Sci. 2019;7(7):1184-92. doi: 10.3889/oamjms.2019.256.
12. Mahmoud EF, Omar OM. Erosive and cariogenic potential of various pediatric liquid medicaments on primary tooth enamel: a SEM study. Dent Med Probl. 2018;55(3):247-54. doi: 10.17219/dmp/91539.
13. Ramanandvignesh P, Gyanendra K, Jatinder Kaur Goswami Mridula D. Clinical and radiographic evaluation of pulpotomy using MTA, biodentine and Er,Cr:YSGG laser in primary teeth - a clinical study. Laser Ther. 2020;29(1):29-34. doi: 10.5978/islsm.20-OR-03.
14. Kumar P, Goswami M, Dhillon JK, Rehman F, Thakkar D, Bharti K. Comparative evaluation of microhardness and

morphology of permanent tooth enamel surface after laser irradiation and fluoride treatment - an in vitro study. Laser Ther. 2016;25(3):201-8. doi: 10.5978/islsm.16-OR-16.
15. Khamverdi Z, Kordestani M, Panahandeh N, Naderi F, Kasraei S. Influence of CO2 laser irradiation and CPPACP paste application on demineralized enamel microhardness. J Lasers Med Sci. 2018;9(2):144-8. doi: 10.15171/jlms.2018.27.
16. Chang NN, Jew JM, Simon JC, Chen KH, Lee RC, Fried WA, et al. Influence of multi-wavelength laser irradiation of enamel and dentin surfaces at 0.355, 2.94, and 9.4 µm on surface morphology, permeability, and acid resistance. Lasers Surg Med. 2017;49(10):913-27. doi: 10.1002/lsm.22700.
17. Haghgoo R, Ahmadvand M, Moshaverinia S. Remineralizing effect of topical NovaMin and nano-hydroxyapatite on caries-like lesions in primary teeth. J Contemp Dent Pract. 2016;17(8):645-9. doi: 10.5005/jp-journals-10024-1905.
18. Taneja V, Nekkanti S, Gupta K, Hassija J. Remineralization potential of theobromine on artificial carious lesions. J Int Soc Prev Community Dent. 2019;9(6):576-83. doi: 10.4103/jispcd.JISPCD_265_19.
19. Joshi C, Gohil U, Parekh V, Joshi S. Comparative evaluation of the remineralizing potential of commercially available agents on artificially demineralized human enamel: an in vitro study. Contemp Clin Dent. 2019;10(4):605-13. doi: 10.4103/ccd.ccd_679_18.
20. Subramaniam P, Pandey A. Effect of erbium, chromium: yttrium, scandium, gallium, garnet laser and casein phosphopeptide-amorphous calcium phosphate on surface micro-hardness of primary tooth enamel. Eur J Dent. 2014;8(3):402-6. doi: 10.4103/1305-7456.137656.
21. Khan AS, AlDahlan BG, Maghrabi NH, Albilali HW, Ahmed SZ, Shah AT, et al. Application of laser on enamel surface with three types of bioactive glasses-based resin infiltrants: an in vitro study. J Mech Behav Biomed Mater. 2023;141:105792. doi: 10.1016/j.jmbbm.2023.105792.