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International Journal of Pharmaceutical Research & Allied Sciences, 2022, 11(2):120-130
https://doi.org/10.51847/tQ2FQHS4VZ

Review Article

ISSN : 2277-3657
CODEN(USA) : IJPRPM

Effect of Bioactive Glass on the Remineralization of Caries Lesion: A Systematic Review

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ABSTRACT

Bioactive glass's most well-known capacity is its bonding ability to bone and promoting bone development. The bioactive glass may mineralize dentine tubules for sensitive teeth to provide relief and prevent caries. Bioactive glass is an emerging therapy for regenerating damaged bone tissue after injury or illness. Its usefulness in the medical profession has led to its implementation in several areas. In 1969, a silicate glass made of sodium, calcium, and phosphorus was the first bioactive glass on the marketUsing the databases PubMed, Medline, and ScienceDirect, a comprehensive review of the literature spanning 2011 to 2022 was conducted. The keywords used were "bioactive glass" and "caries remineralization". 8 studies were included in this systematic review. However, most of them revealed that bioactive glass could not provide enough remineralization, especially when compared to fluoride. Although bioactive glass has shown encouraging signs of remineralization, its effectiveness is not to the standard produced by fluorides. Hence, there is a need to conduct further studies to reassure the importance of bioactive glass as a good replacement for fluoride.

Key words: *Bioactive glass, Dental caries, Remineralization, Systematic review*

INTRODUCTION

Caries are characterized by the loss of mineral content and the degradation of dental hard tissues, and biofilms control it. Demineralizing dental hard tissues results from acid production by cariogenic bacteria, resulting in an oral cavity with a low pH environment for a long time [1-3]. If the surface carious lesions are left untreated, they will eventually become cavities in the tooth [4].

Bioactive glass is an emerging therapy for regenerating damaged bone tissue after injury or illness. Its usefulness in the medical profession has led to its implementation in several areas. In 1969, a silicate glass made of sodium, calcium, and phosphorus was the first bioactive glass on the market. You may get bioactive glass in various forms, including silicate-based and phosphate-based varieties. From the standpoint of material characteristics, bioactive glass is an ideal material. Scaffolds, made of bioactive and biocompatible glass, are used in bone repair to provide a three-dimensional template for bone regeneration [5].

Bioactive glass's most well-known capacity is its bonding ability to bone and promoting bone development. Its high reactivity when in touch with a bone surface is an advantage in bone augmentation and repair. As a first step, putting the material in an aqueous solution causes the particles to adopt a mesoporous structure. The particles will then group together to create an enrichment layer that mimics the apatite substance found in bone and other hard tissues. A layer of hydroxyapatite is formed when ions are exchanged back and forth between the

bioactive glass and the bone surface. In the process of repairing defects, sediments that resemble bone are deposited on the surface of the bone. What happens to teeth is analogous to what happens to bones. The bioactive glass may mineralize dentine tubules for sensitive teeth to provide relief [6].

When utilised as a dental paste, Novamin adheres to the tooth's surface as a bioactive glass and continuously deposits a natural crystalline hydroxyl carbonate. It is a biomimetic mineralizer since it imitates the natural mineralization procedures of the body. Calcium and phosphate ions are swiftly released from the bioactive glass particles when sodium ions from the particles undergo fast exchange with hydrogen cations (in the form of H3O+) in the saliva in the oral cavity, the aqueous environment around the tooth. As sodium is released at first contact with water, the pH of the immediate vicinity rises briefly [7]. The elevated pH aids in the precipitation of calcium phosphate from the additional calcium and phosphate ions supplied by the Bioactive Glass. These interactions eventually cause this layer to crystallize as hydroxycarbonate apatite (HCA). The interaction between the residual Novamin particles and the freshly formed HCA layer results in remineralization of the enamel surface and protection against further demineralization [8].

MATERIALS AND METHODS

A systematic literature review from 2011 to 2022 was performed using databases such as PubMed, Medline, and ScienceDirect. The keywords used were "bioactive glass" and "caries remineralization." PRISMA flowchart was used to describe the selection process of searched articles.

Table 1. Inclusion and exclusion criteria

№	Inclusion criteria	Exclusion criteria
1.	Case-control and randomized control studies	Systematic reviews or meta-analyses or expert opinions, or narrative reviews
2.	Published between 2011 and 2022	Out of the specified time range
4.	English language of publication	Language other than English
7.	In vivo (humans)	In vitro

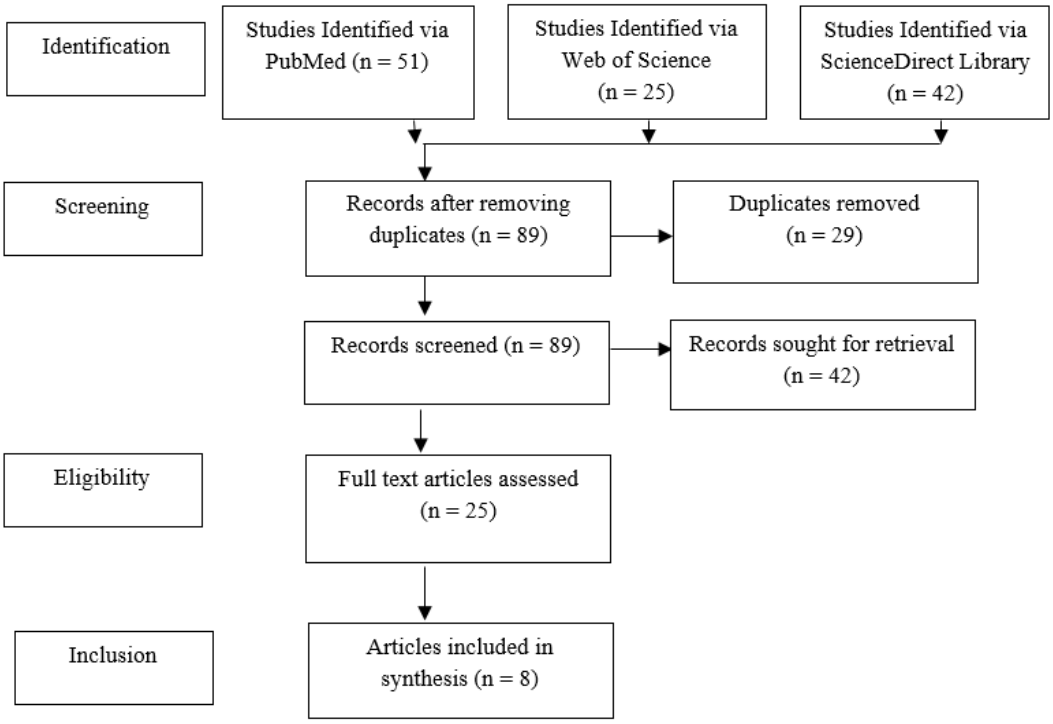

Figure 1. PRISMA Flow Diagram

Risk of bias assessment

The Cochrane risk of bias assessment method was used to assess the quality of the studies included.

Table 2. Summary of Cochrane Risk of Bias Assessment

Study	Selection Bias/Appropriate control selection/baseline characteristics similarity	Selection bias in randomization	Selection bias in allocation concealment	Performance-related bias in blinding	Reporting bias/Selective reporting of outcomes	Detection bias Blinding outcome assessors	Accounting for confounding bias
Narayana *et al*., (2014)	+	+	+	+	+	+	-
Mehta *et al*., (2014)	+	+	+	+	-	+	-
Rajendran *et al*., (2019)	+	+	+	+	+	_	+
Sharda *et al*., (2021)	+	+	+	+	+	+	-
Alhussain *et al*., (2018)	+	-	+	+	+	+	+
Körner *et al*., (2020)	+	+	+	-	+	+	+
Kim *et al*., (2021)	+	+	+	+	+	+	+
Hsu *et al*., (2021)	+	+	+	+	+	+	-

RESULTS AND DISCUSSION

The results, objectives, participants, follow-up periods, materials of all included studies are described in **Table 3**.

Table 3. Summary of findings of selected studies

Author name participants	objective	technique	Follow up period	Statistical test	groups	materials	outcome
Narayana *et al*., (2014) [9] 20	To investigate the Remineralization effectiveness of bioactive glass on a carious lesion	energy dispersive X-ray spectroscopy	10 days	ANOVA, Student's t-test, and Tukey's multiple comparison tests	5	Test Group A - Bioactive glass (Novamin) , Test Group B - Fluoride tooth paste (Amflor) , Test Group C - CPP-ACP (Tooth mousse) , Test Group D - CPP-ACPF (Tooth mousse plus) , Test Group E (control group)	When the findings for Group A were compared to those for Group B, they were statistically significant, suggesting that Group A had a higher degree of remineralization.

Sharda *et al*., (2021) [12]	Rajendran *et al*., (2019) [11]	Mehta *et al*., (2014) [10]
45	30	
This research aimed to evaluate the effectiveness of TF mono-therapy vs. a combination of TF and CPP-ACP/bioactive glass/xylitol/ozone on high-risk people in terms of remineralization and caries prevention.	Analyzing the Remineralizing Effects of Bioactive Glass Paste and Casein Phosphopeptide-Amorphous Calcium Phosphate Topical Cream.	evaluating the casein phosphopeptide-amorphous calcium phosphate and bioactive glass remineralization capability on the first carious lesion
light-induced fluorescence (QLF), visual inspection, or laser fluorescence methods	energy dispersing X-ray analysis, SEM	Vickers microhardness testing machine
28 days	10 days	
WSLs regression	Kruskal-Wallis, ANOVA, and Mann-Whitney tests	Bonferroni method (post-hoc tests)
2		2
CPP-ACP-TF combined therapy using CPP-ACP/ Xylitol/ Bioactive glass/ Ozone along with Topical Fluoride over TF mono-therapy	Group I (n=15) remineralized with Regular Toothpaste without a specific remineralizing agent Group II (n=15) contains toothpaste containing calcium sodium-phosphosilicate (Novamin). Group III (n=15) Topical cream containing casein phosphopeptide-amorphous calcium phosphate	Group A: BAG containing dentifrice and Group B: CPP-ACP containing dentifrice
The sole clinical experiment that matched the inclusion criteria for this review found no statistically significant difference in post-intervention visual change when comparing toothpaste containing bioactive glass to toothpaste containing just fluoride.	The results showed that remineralizing the demineralized specimen using novamin-containing dental paste increased the calcium and phosphorus levels, respectively, which was statistically significant ($p<0.001$) compared to the demineralized samples.	The difference in mean microhardness between the groups after remineralization was found to be statistically significant after remineralization ($P < 0.05$), indicating changes in the mineralization of the tooth samples.

Hsu *et al*., (2021) [16]	Kim *et al*., (2021) [15]	Körner *et al*., (2020) [14]	Alhussain *et al*., (2018) [13]
22	13	100	24
Analysis of Fluoride and Bioactive Glass' Remineralization Potentials on Hydroxyapatite (HA) Discs, Qualitative	The purpose of this study was to determine how a new experimental bioactive glass (BAG)-containing varnish affected the remineralization of enamel.	Effects of Using Bioactive Glasses or a Hydroxyapatite Toothpaste More Frequently on the Remineralization of Artificial Lesions	use a novel fluoride-incorporated bioactive glass dentifrice to research the remineralization of synthetic carious lesions
SEM, XPS	(FE-SEM),EDS,	Advanced transversal microradiography; aTMR)	Vickers tester
15 DAYS	14 days	28 days	14 days
	ANOVA and Tukey's post hoc	Kruskal-Wallis test followed by a post hoc Conover test	Kruskal–Wallis test
4	8	2	3
(1) Sensodyne toothpaste with fluoride; (2) Sensodyne toothpaste with fluoride and bioactive glass (NovaMin); (3) Tom's Toothpaste without fluoride or bioactive glass (NovaMin); and (4) Tom's Toothpaste with a bioactive glass (NovaMin)	hydroxyapatite (HAP) or fluorapatite (FAP)	a fluoride-free, hydroxyapatite-containing toothpaste (HTP) and two distinct bioactive glasses (FTP).	group1 (negative control group; distilled water), group2 (positive control group; fluoride toothpaste) and group3 (test group; BioMinTM F toothpaste).
When compared to the other groups, Tom's toothpaste with simply NovaMin showed the greatest potential for remineralization.	When compared to brushing with 1,400 ppm FTP, the additional administration of both bioactive glasses and the substitute HTP brushing significantly reduced the amount of remineralization.	This hypothesis appears to be supported by the study's findings, which show that much less remineralization was seen in the groups that contained bioactive glass.	When the post-demineralization and post-remineralization values within each group were compared to the baseline values, each group showed significant differences ($p < 0.05$).

Twenty human molars were acquired by Narayana *et al*. [9], all of which had to be extracted due to periodontal disease. The participants are divided into five distinct groups. Those in group A were given no treatment (the control), those in group B received fluoride toothpaste (Amflor), those in group C received tooth mousse, those in group D received tooth mousse plus, and those in group E were given a demineralized sample. One-way

analysis of variance revealed that the group means were significantly different from one another. After ten days, all test groups were analysed using human hair spherical electron microscopy (HRSEM) and quantitative evaluation using energy dispersive X-ray spectroscopy (EDXR). The data were analysed using one-way analysis of variance (ANOVA), a student's t-test, and Tukey's multiple comparison tests. Alaudin and Fontana came to the conclusion that Novamin dentifrice resulted in significantly more remineralization than fluoride dentifrice based on their confocal laser scanning microscope investigation. Between Group A and Group B, there was a statistically significant difference, indicating that Group A had a higher amount of remineralization. Calcium was found to have much higher atomic and weight percentages than the control. Mineral deposits were seen along the porous flaws in a consistent distribution in the HRSEM image. The absence of evidence suggests that bioactive glass has no effect. Hence the alternative hypothesis that it does must be accepted. There was a smaller atomic and weight proportion of fluoride in Group C compared to Group B and Group D. This is supported by the fact that Novamin (SHY-NM) is not a fluoride-containing product.

According to Mehta *et al*.'s (2014) study [10], 30 human premolars in good health were extracted and used in an orthodontic investigation. Similar to how it had been done for B-SMH, VMT was utilised to confirm R-SMH. Following that, we divided the samples equally between the two groups (n = 15) using a random number generator. Dental products were divided into Groups A and B based on whether they contained BAG (SHY-NM; Group Pharmaceuticals; India) or CPP-ACP (GC tooth mousse; Recaldent; GCcorp; Japan). The pH was cycled daily for ten days. We measured the SMH of remineralized samples. The Bonferroni procedure was used for multiple comparisons within groups after an analysis of variance was performed (post-hoc tests). The researchers show us the differences in microhardness between Group A and Group B at each time point. There was no statistically significant difference in the two groups' mean microhardness before and after demineralization (P > 0.05). This suggests that the tooth samples were all very close in hardness following demineralization, which would provide a null result in statistical analysis. Changes in the mineralization of the tooth samples were shown by a significant difference in mean microhardness between the groups following remineralization (P 0.05).

The research performed by Rajendran *et al*. (2019) [11] shows that 45 permanent human premolar teeth were gathered, all of which had been recently removed (for orthodontic purposes). Demineralization using McInnes demineralizing solution was performed on all samples from groups I, II, and III. The mean and standard deviation were determined by using descriptive statistics. The Kruskal-Wallis, one-way analysis of variance, and Mann-Whitney U tests were used for the testing. Normal toothpaste without any remineralizing additives was part of the remineralization routine. A topical lotion comprising casein phosphopeptide-amorphous calcium phosphate was applied by Group III (n = 15). The toothpaste used by Group II (n = 15) contained calcium sodium phosphosilicate (Novamin). We analysed the topographical enamel surface pictures and energy dispersion of all the healthy samples under a scanning electron microscope. Calculated mineral (calcium and phosphorus) levels were estimated quantitatively across all three groups using X-ray analysis. In Group II, the average calcium and phosphorus levels for healthy enamel were 65.27 0.58 and 20.79 0.78, respectively. The average calcium and phosphorus levels in the deionized water were 55.09 0.54 and 15.71 0.57, respectively. Mean calcium and phosphorus values obtained after remineralization of the demineralized specimen with novamin-containing toothpaste were 61.29 0.62 and 17.56 0.43, respectively; these values were greater than those of the demineralized samples and statistically significant (p 0.001). When the mean calcium and phosphorus levels of the groups were compared, statistically significant differences were found, with group III having the highest mean calcium and phosphorus levels and group I having the lowest.

Remineralizing early-stage lesions and lowering the salivary S mutants load are significantly more effective with CPP-ACP-TF combination treatment using CPP-ACP/Xylitol/Bioactive glass/Ozone in addition to Topical Fluoride than with TF mono-therapy, according to Sharda *et al*. (2021) [12]. The main analytical methods employed in this investigation were quantitative light-induced fluorescence (QLF), visual inspection, and laser fluorescence. The remineralization potential is calculated using the results they offer. The results also demonstrate that combining xylitol and fluoride therapy can more effectively stop caries from progressing. It is impossible to comment on the increased caries prevention effectiveness of bioactive glass over fluoride alone due to a lack of scientific evidence. The combination treatment, however, was demonstrated to be superior when two trials were combined and WSL's regression was assessed visually using the Gorelick Index. When comparing the remineralization capacity of CPP-ACP-TF to that of TF monotherapy, as assessed by QLF, the current study indicated no statistically significant difference between the two groups. The release of Ca2+, Na+, PO43, and Si4 ions, which increases the local pH and osmotic pressure, is attributed to the possible use of

calcium sodium phosphor-silicate (Bioactive glass/NovaMin) for caries prevention. The one clinical trial that was relevant to this meta-spectrophotometer analysis revealed no discernible difference between fluoride-only toothpaste and toothpaste including bioactive glass in terms of post-intervention visual change.

24 extracted human teeth were donated for this study by Alhussain *et al*. (2018) [13], who conducted their research at the College of Dentistry at Imam Abdulrahman bin Faisal University in Dammam, Saudi Arabia. For statistical comparisons between the three groups, the Kruskal-Wallis test was applied. The surface micro-hardness was assessed using a tool known as a Vickers tester. Between post-remineralization and post-demineralization readings, Group 3 had the highest difference (mean VHN = 118.73), followed by Group 2 (mean VHN = 60.54), and Group 1 (mean VHN = 47.44). The BioMin F group fared better than the other two groups at remineralizing the demineralized enamel structure, although neither group's structure could be restored to baseline levels with 800 strokes. Additionally, statistically significant (p 0.05) differences were seen in all groups when comparing values before and after demineralization and remineralization.

The goal of the study by Körner *et al*. (2020) [14] was to assess and compare the impact of two different bioactive glasses on the remineralization behaviour of initial caries lesions using 100 bovine enamel samples randomly divided into five groups of 20 samples each. The two bioactive glasses were hydroxyapatite-containing, fluoride-free Toothpaste (HTP) and fluoride toothpaste (FTP). For the statistical study of integrated mineral loss, Kruskal-Wallis and post hoc Conover tests were employed. This study's findings provide credence to this theory since remineralization was dramatically reduced in the bioactive glass groups compared to those to which just the FTP was applied. The FTP + BGnano and FTP + BGamorph groups underwent an additional application procedure of the bioactive glass slurry in contrast to the NC, HTP, and FTP groups, who received no additional intervention, so it is crucial to keep in mind that there is a potential for bias introduced by this fact.

This research by Kim *et al*. (2021) [15] aimed to assess the effectiveness of an experimental varnish containing bioactive glass (BAG) on enamel remineralization. Each of the eight treatment groups contained thirteen samples of enamel. Microhardness tests (n = 3), field emission scanning electron microscopy (FE-SEM) in conjunction with energy dispersive X-ray spectroscopy (EDS) (n = 5), and X-ray diffraction (XRD) analyses (n = 5) were carried out to assess the remineralization impact of three varnishes with and without ultrasonication. The findings of the microhardness test were examined using a one-way analysis of variance and Tukey's post hoc comparison (P 0.05). Three varnishes significantly increased the microhardness of demineralized enamel (P 0.05). Out of the three varnishes examined, the one with the BAG had the strongest microhardness, according to an experiment (P 0.05). Tooth Mousse and BAG-containing varnish groups both experienced a decrease in microhardness after ultrasonication (P 0.05). After examining three different varnishes, field emission scanning electron microscopy (FE-SEM) and X-ray powder diffraction (XRD) revealed precipitates of either hydroxyapatite (HAP) or fluorapatite (FAP) crystals. Remineralizing early carious lesions or a demineralized enamel surface may be possible therapeutically using the novel experimental varnish that contains BAG.

The purpose of the study by Hsu *et al*. (2021) [16] was to examine the effects of adding fluoride and/or bioactive glass (NovaMin) on the remineralization of hydroxyapatite (HA) discs, which are intended to mimic the enamel surface of real teeth. Surface morphologies were analyzed using scanning electron microscopy (SEM), and surface compositions were analyzed with X-ray photoelectron spectroscopy (XPS). There was a total of 22 hydroxyapatite (HA) discs ("Ca5(PO4)3(OH)") used in the experiment. Phosphoric acid was used to etch HA discs. Then the discs were treated with four different kinds of toothpaste: One Sensodyne toothpaste has fluoride, two Sensodyne toothpastes contain fluoride and bioactive glass (NovaMin), three Tom's toothpastes don't contain fluoride or bioactive glass (NovaMin), and four Tom's toothpastes do (NovaMin). The engraved discs were treated with various toothpastes for 15 days, once per day for two minutes. SEM was used to evaluate surface morphologies, and X-ray photoelectron spectroscopy (XPS) was used to determine surface composition. Among the three groups, Tom's Toothpaste with only NovaMin demonstrated the highest level of remineralization. Tom's toothpaste has peculiar qualities because it contains bioactive glass (NovaMin) (group 4). The etched HA crystals grew noticeably closer to one another, much as the fluoride-containing (group 1) and fluoride plus bioactive glass-containing (NovaMin) (group 2) toothpastes induced the HA crystals to grow closer to one another and create granules between the crystals. Additionally, the etched HA crystals' form changed or grew, indicating significant remineralization.

The human body contains the minerals sodium, calcium, phosphorus, and silica (sodium calcium phosphosilicate), which can also be found in bioactive glass. The ions released by bioactive glass immediately form hydroxycarbonate apatite (HCA), bypassing the intermediary ACP phase, which other calcium phosphate methods require. These particles adhere to the teeth, releasing ions and remineralizing the enamel even after the

treatment has ended. In-vitro studies have demonstrated that these particles may release ions and convert them into HCA for up to two weeks. [17] The particles will eventually crystallize into hydroxyapatite; the mineral used to construct teeth and bone. It is hypothesized that the HCA layer aids in the remineralization of teeth. Bioactive glass experiences an instantaneous three-stage surface reaction in a water environment that includes leaching and exchanging cations, network SiO2 dissolution, and the precipitation of calcium and phosphate to create an appetite layer. There is evidence to suggest that bioactive glass may help restore lost minerals. Therefore we must reject the null hypothesis and go on. There was a smaller atomic and weight proportion of fluoride in Group C compared to Group B and Group D. This is true since Novamin (SHY-NM) is a non-fluoridated alternative to regular toothpaste. The availability of fluoride is crucial for its caries-preventive action. The dissolution of the fluoride-containing substance and its adherence to the surface determine the bioavailability of fluoride. Sodium fluoride, sodium monofluorophosphate, and amine fluoride are the most common fluoride formulations utilized as carriers for fluoride ions in dentifrices. Amine fluoride's impact on enamel remineralization has been the subject of laboratory and human studies. The solubility of NaF, sodium monofluorophosphate, and amine fluoride may have an impact on the bioavailability of fluoride in saliva as well as the demineralization and remineralization potential of enamel [18].

In the current investigation, two dentifrices that are not typically the primary active components in widely used dentifrices were compared for their remineralization capacity. Examining changes in the surface layer is important due to the relevance of this area in caries development; consequently, SMH measurement is an appropriate tool for investigating the de-remineralization process. Microhardness testing is the best option for materials with a fine microstructure, non-homogeneity, or brittleness to cracking. Studying the effects of demineralization and remineralization using SMH indentations is quick, easy, and doesn't damage the hard surface.

Three studies [19-21] were combined to analyze the effects of CPP-ACP-TF combination therapy on fluorescence and lesion area, including 105 individuals in the treatment group and 118 in the control group. Neither the DF nor the lesion area was significantly different after the intervention. Pooling of two trials [19, 22] utilizing the general inverse variance approach to evaluate the visual change in WSLs according to the Gorelick criterion. When comparing the efficacy of fluoride mono-therapy vs. the CPP-ACP-TF combination, it was shown that the latter was superior in reducing the WSLs.

For the objective of remineralization, participants in Group II in the current research utilized a toothpaste containing bioactive glass (novamin). Casein phosphopeptide-amorphous calcium phosphate was applied topically to group III. Caries models have shown that CPP-ACP nanocomplexes effectively prevent and reverse enamel defects. CPP-ACP effectively halts enamel demineralization and stimulates remineralization in its earliest stages. Clinical in situ experiments demonstrated a remineralizing impact on teeth for a limited time, and an in vivo randomized control study demonstrated a caries-preventing efficacy over the long term [23]. ACP is not only held in place by the CPP, but it is also delivered to the tooth surface and kept there by the CPP [24]. The location of amorphous calcium phosphate on the tooth surface, where it buffers the free calcium and phosphate ion activities, is thought to be how CPP-ACP exerts its anti-cariogenic effects. This helps to keep the tooth enamel supersaturated, which prevents demineralization and promotes remineralization [25].

The present surface micro-hardness research indicated that, compared to fluoride-based toothpaste and distilled water, BioMin F toothpaste had a greater remineralizing effect. Because of its unique chemical makeup, BioMin F has more remineralization capability than regular fluoride toothpaste. Calcium sodium phosphosilicate (BG) is the typical formula and does not include fluoride. Fluoride may be found in the BioMin F toothpaste's BG formula, which is strong in phosphate [26]. When BG is placed in the mouth, ionic exchange activities take place, leading the glass to dissolve and release calcium (Ca^{2+}) and phosphate (PO_4^-) ions, which results in the development of FAP, which is more acid-resistant and is particularly desirable for a number of dental applications. Since it helps to maintain the glass's network connection and ensures the production of FAP, it has been demonstrated that the high phosphate content of BG toothpaste is advantageous [27].

The current investigation shows that when bioactive glasses were employed in addition to brushing with 1,400 ppm FTP, remineralization was significantly reduced. The Schott bioactive glass is a typical amorphous bioactive glass that has received praise for its capacity to remineralize and strengthen human hard tissue as well as help repair enamel erosion brought on by acid by releasing ions that can build a mineral matrix similar to hydroxyapatite. The bioactive glass employed in Actimins appears to have SiO_2 as its crystalline phase, and the glass contains a bioactive, nanocrystalline powder. Actimins describes itself as a de-sensitizer that also purports to raise intraoral pH, release minerals (silica, calcium, and phosphorous), and crystallise a developing calcium

and phosphate layer into carbonated hydroxyapatite, aiding tooth remineralization. The hardness of the enamel surface is greatly increased by bioactive glasses [28].

The ability of BAG to remineralize enamel has been the subject of much research. It has been observed that the microhardness of the enamel surface degraded from below by 45S5 BAG paste has increased. Studies have shown that applying BAG paste to early-stage enamel erosion lesions forms an abrasion-resistant layer of HAP [29]. Studies on remineralizing carious-like lesions in permanent teeth found that BAG-containing toothpaste was more effective than fluoride-containing toothpaste [30]. Caries in primary teeth were remineralized by BAG much as they were by CPP-ACP and Toothpaste containing 500 ppm fluoride. Previous research has shown that BAG is most often applied as a paste. Unfortunately, the enamel surface lacks the substantivity necessary for this shape [31].

To demineralize the enamel, 40% phosphoric acid was used to etch the HA discs. As was to be expected, Tom's fluoride-free and NovaMin-free Toothpaste failed to stimulate remineralization since it lacked essential ingredients. Tom's of Maine fluoride-free and NovaMin-free toothpaste contains hydrated silica for polishing and cleansing and sodium bicarbonate for breath freshening and whitening. In their research, Hamza *et al*. tested several kinds of toothpaste' abrasiveness and cleansing power. Hydrated silica was more abrasive than other abrasives [32]. This might help explain our observation that Tom's toothpaste and etched HA discs have comparable geometries.

CONCLUSION

Although bioactive glass has shown encouraging signs of remineralization, its effectiveness is not to the standard produced by fluorides. Hence, there is a need to conduct further studies to reassure the importance of bioactive glass as a good replacement of fluoride.

ACKNOWLEDGMENTS : We would like to acknowledge the help of Riyadh Elm University research center.

CONFLICT OF INTEREST : None

FINANCIAL SUPPORT : None

ETHICS STATEMENT : This study fulfills the ethical requirements of Riyadh Elm University.

REFERENCES

1. Remizova AA, Sakaeva ZU, Dzgoeva ZG, Rayushkin II, Tingaeva YI, Povetkin SN, et al. The role of oral hygiene in the effectiveness of prosthetics on dental implants. Ann Dent Spec. 2021;9(1):39-46.
2. Asgari I, Soltani S, Sadeghi SM. Effects of iron products on decay, tooth microhardness, and dental discoloration: a systematic review. Arch Pharm Pract. 2020;11(1):60-82.
3. Alhamwi N, Al Jarbou F, Ourfhli A, Alfaris F, Algannass T, AlSaffan A, et al. Perception and Experience of Dental Students Regarding E-Learning Education In The Universities Of Riyadh. Pharmacophore. 2020;11(6):67-73.
4. Wong A, Subar PE, Young DA. Dental caries: an update on dental trends and therapy. Adv Pediatr. 2017;64(1):307-30.
5. Pitts NB, Zero DT, Marsh PD, Ekstrand K, Weintraub JA, Ramos-Gomez F, et al. Dental caries. Nat rev Dis primers. 2017;3(1):1-6.
6. Jones JR. Review of bioactive glass: from Hench to hybrids. Acta Biomater. 2013;9(1):4457-86.
7. Ali S, Farooq I, Iqbal K. A review of the effect of various ions on the properties and the clinical applications of novel bioactive glasses in medicine and dentistry. Saudi Dent J. 2014;26(1):1-5.
8. Shivaprasad BM, Padmavati P, Nehal NS. Chair side application of NovaMin for the treatment of dentinal hypersensitivity-A novel technique. J Clin Diagnostic Res. 2014;8(10):ZC05.
9. Narayana SS, Deepa VK, Ahamed S, Sathish ES, Meyappan R, Kumar KS. Remineralization efficiency of bioactive glass on artificially induced carious lesion an in-vitro study. J Indian Soc Pedod Prev Dent. 2014;32(1):19.

10. Mehta AB, Kumari V, Jose R, Izadikhah V. Remineralization potential of bioactive glass and casein phosphopeptide-amorphous calcium phosphate on initial carious lesion: An in-vitro pH-cycling study. J Conserv Dent. 2014;17(1):3.
11. Sharda S, Gupta A, Goyal A, Gauba K. Remineralization potential and caries preventive efficacy of CPP-ACP/Xylitol/Ozone/Bioactive glass and topical fluoride combined therapy versus fluoride mono-therapy–a systematic review and meta-analysis. Acta Odontol Scand. 2021;79(6):402-17.
12. Rajendran R, Kunjusankaran RN, Sandhya R, Anilkumar A, Santhosh R, Patil SR. Comparative evaluation of remineralizing potential of a paste containing bioactive glass and a topical cream containing casein phosphopeptide-amorphous calcium phosphate: An in vitro study. Pesqui bras odontopediatria clin integr. 2019;19.
13. Alhussain AM, Alhaddad AA, Ghazwi MM, Farooq I. Remineralization of artificial carious lesions using a novel fluoride incorporated bioactive glass dentifrice. Dent Med Probl. 2018;55(4):379-82.
14. Körner P, Schleich JA, Wiedemeier DB, Attin T, Wegehaupt FJ. Effects of additional use of bioactive glasses or a hydroxyapatite toothpaste on remineralization of artificial lesions in vitro. Caries Res. 2020;54(4):336-42.
15. Kim HJ, Mo SY, Kim DS. Effect of bioactive glass-containing light-curing varnish on enamel remineralization. Materials. 2021;14(13):3745.
16. Hsu SM, Alsafadi M, Vasconez C, Fares C, Craciun V, O'Neill E, et al. Qualitative Analysis of Remineralization Capabilities of Bioactive Glass (NovaMin) and Fluoride on Hydroxyapatite (HA) Discs: An In Vitro Study. Materials. 2021;14(14):3813.
17. Madan N, Sharma V, Pardal D, Madan N. Toothremineralization using bio-active glass — A novel approach. J Acad Adv Dent Res. 2011;2(2):45-9.
18. Burwell AK, Litkowski LJ, Greenspan DC. Calcium sodium phosphosilicate (NovaMin): Remineralization potential. Adv Dent Res. 2009;21(1):35-9.
19. Bröchner A, Christensen C, Kristensen B, Tranæus S, Karlsson L, Sonnesen L, et al. treatment of postorthodontic white spot lesions with casein phosphopeptide-stabilised amorphous calcium phosphate. Clin Oral Invest. 2011;15(3):369-73.
20. Sitthisettapong T, Doi T, Nishida Y, Kambara M, Phantumvanit P. Effect of CPP-ACP paste on enamel carious lesion of primary upper anterior teeth assessed by quantitative light-induced fluorescence: a one-year clinical trial. Caries Res. 2015;49(4):434-41.
21. Esenlik E, Bolat E. Efficacy of a casein phosphopeptide amorphous calcium phosphate (CPP-ACP) paste in preventing white spot lesions in patients with fixed orthodontic appliances: a prospective clinical trial. Eur J Paediatr Dent. 2016;17(4):274-80.
22. Al-Batayneh OB, Bani Hmood EI, Al-Khateeb SN. Assessment of the effects of a fluoride dentifrice and GC Tooth Mousse on early caries lesions in primary anterior teeth using quantitative light induced fluorescence: a randomised clinical trial. Eur Arch Paediatr Dent. 2020;21(1):85-93.
23. Poorni S, Kumar RA, Shankar P, Indira R, Ramachandran S. Effect of 10% sodium ascorbate on the calcium:phosphorus ratio of enamel bleached with 35% hydrogen peroxide: An in vitro quantitative energy-dispersive X-ray analysis. Contemp Clin Dent. 2010;1(4):223-6. doi:10.4103/0976-237X.76388
24. Jayarajan J, Janardhanam P, Jayakumar P, Deepika. Efficacy of CPP-ACP and CPP-ACPF on enamel remineralization - An in vitro study using scanning electron microscope and diagnodent. Indian J Dent Rest. 2011;22(1):77-82. doi:10.4103/0970-9290.80001
25. Wang Y, Mei L, Gong L, Li J, He S, Ji Y, et al. remineralization of early enamel caries lesions using different bioactive elements containing toothpastes: An in vitro study. Technol Health Care. 2016;24(5):701-11.
26. Somaraj V, Shenoy RP, Shenoy Panchmal G, Kumar V, Jodalli PS, Sonde L. Effect of herbal and fluoride mouth rinses on Streptococcus mutans and dental caries among 12–15-year-old school children: A randomized controlled trial. Int J Dent. 2017;2017:5654373.
27. Clark MB, Slayton RL. Section on Oral Health. Fluoride use in caries prevention in the primary care setting. Pediatrics. 2014;134(3):626-33.
28. Milly H, Festy F, Watson TF, Thompson I, Banerjee A. Enamel white spot lesions can remineralise using bio-active glass and polyacrylic acid-modified bio-active glass powders. J Dent. 2014;42(2):158-66.
29. Bakry AS, Marghalani HY, Amin OA, Tagami J. The effect of a bioglass paste on enamel exposed to erosive challenge. J Dent. 2014;42(11):1458-63.

30. Golpayegani MV, 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. 2012;9(1):68-75.
31. Benjasuwantep P, Rirattanapong P, Vongsavan K. The remineralization effect of bioactive glass on enamel caries-like lesions in primary teeth. Southeast Asian J Trop Med. 2017;48:1127-32.
32. Hamza B, Tanner M, Attin T, Wegehaupt FJ. Dentin Abrasivity and Cleaning Efficacy of Novel/Alternative Tooth-pastes. Oral Health Prev Dent. 2020;18(1):713-8.