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45S5 Bioglass paste is capable of protecting the enamel surrounding orthodontic brackets against erosive challenge

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Abstract:

OBJECTIVES: This study aimed at evaluating the effect of using a 45S5 bioglass paste and a topical fluoride as protective agents against acidic erosion (resembling acidic beverage softdrinks intake) for enamel surrounding orthodontic brackets.

MATERIALS AND METHODS: Sample of 21 freshly extracted sound incisor and premolar teeth was randomly divided into three equal groups: a bioglass group (Bioglass) (NovaMin, 5-mm average particle, NovaMin Technology), a Fluoride group (Fluoride) (Gelato APF Gel, Keystone Industries), and a control group (Control). Orthodontic brackets were bonded to the utilized teeth using MIP (Moisture Insensitive Primer) and Transbond PLUS color change adhesive. All specimens were challenged by 1% citric acid for 18 min. The top enamel surfaces next to the orthodontic brackets were examined by SEM-EDS. Wilcoxon Signed-Rank test was used to compare the area covered by the 45S5 bioglass paste before/after erosion $P < 0.05$.

RESULTS: 45S5 bioglass paste application resulted in the formation of an interaction layer that significantly resisted erosion challenge $P < 0.05$. The fluoride and control specimens showed signs of erosion of the enamel next to the orthodontic brackets ($P < 0.05$).

CONCLUSION: 45S5 bioglass paste can efficiently protect the enamel surfaces next to orthodontic brackets for acidic erosion challenges.

Keywords:

45S5 Bioglass, erosion, orthodontic brackets

Introduction

Demineralization of enamel around orthodontic brackets is a clinical problem faced by many orthodontists worldwide^[1,2] because surface irregularities of the bands, brackets, and other attachments can act as plaque stagnation areas, causing the increase of the cariogenic streptococcus bacterial in these orthodontic patients' oral cavities.^[1,3] Moreover, the spread of improper diet habits and specially

the increased consumption of erosive drinks in hot regions of the world^[4] may complicate the dental problems of orthodontic patients through the development of erosive lesions.^[4] Prevention of acidic erosive lesions by applying topical fluoride on the enamel of high caries risk patients can help in decreasing the incidence of enamel demineralization;^[5,6] however, topical fluoride application to orthodontic patients treated with fixed orthodontic appliances may affect the surface properties of the brackets and orthodontic wires used for treatment.^[7] Moreover, previous research

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reported the possibility of using other materials for protecting enamel against various acidic attacks such as bonding orthodontic brackets with fluoride releasing bonding agents,^[8] the use of nano particles to modify the cariogenic oral flora in orthodontic patients,^[9] the use of caseinphosphopeptides-amorphous calcium phosphate containing agents,^[10] the use of antiseptics as chlorhexidine to decrease streptococcus levels in high caries risk orthodontic patients,^[11] probiotics, polyols, sealants, laser, tooth bleaching agents, resin infiltration, and microabrasion.^[9,12]

Another strategy for preventing the development of acidic erosive lesions involved the use of orthodontic sealant prior to bonding orthodontic bracket to enamel. It was suggested that orthodontic sealants can protect the prone areas adjacent to the orthodontic bracket from acidic attacks either from bacterial or non-bacterial origin.^[13]

45S5 bioglass is a bioactive glass that was introduced in the 1960s and proved its efficiency in treating commuted fractures and increased the success rate of metallic artificial joints implanted in humans through its capability in producing a layer of hydroxyapatite on its surface that bonded to the surrounding human soft and hard tissues.^[14] 45S5 bioactive glass was introduced in dentistry as a ridge augmentation material and as a coating material for dental implants;^[14] however, its application for enamel and dentin lesions treatment was recently introduced,^[15] it was suggested that the 45S5 bioglass can form a layer rich in calcium and phosphate that had the ability to remineralize the enamel and dentin lesions^[16,17] and showed good biocompatibility to pulp cells.^[18] The formed layer was resistant to the brushing abrasion in oral cavity. Moreover, it was able to restore early erosive enamel lesions with complete loss of hydroxyapatite crystals content.^[19]

In this study, the efficacy of using a bioglass paste as a protective enamel sealant against an erosive challenge prior to bonding of orthodontic brackets was tested.

The null hypothesis adopted in this study is that the bioglass paste will have no effect in protecting the enamel surface against an erosive challenge.

Materials and Methods

The experimental procedures and the materials used are summarized in Figure 1 and Table 1. About 21 freshly extracted sound incisor and premolar teeth were randomly divided into three equal groups: a bioglass group (Bioglass), a fluoride group (Fluoride), and a control group (Control) that received no remineralization treatment before or after bracket bonding. All specimens were covered with a nail varnish except the facial surface which was left uncovered.

Bioglass application

Bioglass powder (NovaMin, 5 mm average particle, NovaMin Technology), which contains 24.5 wt% Na₂O, 24.4 wt% CaO, 6 wt% P₂O₅, and 45 wt% SiO₂, was mixed by a spatula with diluted aqueous solution of phosphoric acid as described previously on a glass slab for 1 min to form a paste with pH 2.^[16] The prepared paste was applied with a microbrush on the facial surfaces of teeth of the bioglass group. Then, a thin coat of bonding agent (PALFIQUE Bond, Tokuyama Dental, Japan) was applied and light-cured for 10 seconds. Specimens were preserved in distilled water for 24 h. After that, the excess bioglass material was removed with a stream of air-water spray.

Brackets bonding

Etching of enamel surfaces with 37% phosphoric acid was performed for 15 s then rinsed with air-water stream, followed by thorough drying. A liberal coat of Transbond™ MIP Moisture Insensitive Primer (3M Unitek) was applied to etched surfaces then gently dried for 5 s. A small amount of Transbond PLUS color change adhesive (3M Unitek) was dispensed onto the base of orthodontic brackets (Unitek™ Gemini Metal Brackets, 3M Unitek) which were placed on teeth surfaces and adjusted to final position. Brackets were then pressed and excess adhesive was removed, then light cured for 5 s mesially, and 5 s distally.

Fluoride application

Specimens of the Fluoride group had the enamel surface next to the brackets treated with 1.23% acidulated phosphate fluoride gel (Gelato APF Gel, Keystone Industries) for 5 min, then wiped with moistened cotton pellet.

Erosive challenge

Specimens of the three groups were challenged by a buffered demineralizing solution, which is composed of 1% citric acid for 18 min^[20] that was continuously stirred by a magnetic stirrer.

SEM/EDS (scanning Electron microscope/energy-dispersive x-ray spectroscopy) top surface examination

Specimens from each group had their top enamel eroded surface examined by the SEM/EDS (JCM-6000 NeoScope, Jeol, Akishima, Japan). All specimens were gradually dehydrated in an ascending ethanol series (50%–100%), gold coated, and the specimens' surface chemical characterization and morphological features were examined by SEM/EDS. The percentage of coverage by the 45S5 bioglass Interaction layer to the enamel surface was compared using the Wilcoxon Signed-Rank test^[16] before/after erosion ($P < 0.05$).

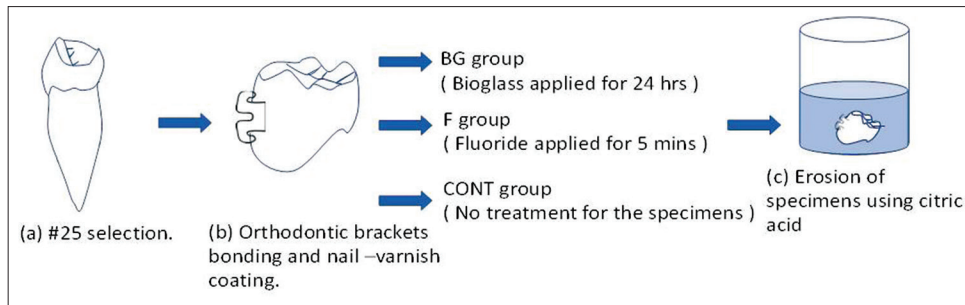


Figure 1: Summary of the experimental procedures

Results

FE-SEM top surface examination

The untreated enamel surface revealed a smooth surface [Figure 2a and b]. The Control group and the Fluoride group [Figure 2c-f] revealed rough enamel surface in which the borders of the enamel prisms were evident due to the erosion challenge. Bioglass-treated specimens showed the coverage of the whole surface by crystalline structures [Figure 2g and h] after exposure to the acid challenge.

Chemical characterization by EDS analysis for all groups are shown in Table 2. The Control and Fluoride groups showed similar content of phosphorus and calcium. Bioglass group specimens showed that the newly formed layer was rich in calcium and phosphate with the presence of trace amounts of silica. Wilcoxon Signed-Rank test showed that the percentage of coverage of the formed interaction layer onto the enamel surface was not significantly changed after the erosion challenge $P < 0.05$.

Discussion

The null hypothesis adopted in this study was rejected. The Interaction layer formed after the bioglass paste application. Bioglass paste protected the enamel surface (next to orthodontic brackets) against an erosive challenge.

The introduction of orthodontic sealants and their application on the enamel surfaces under and surrounding the orthodontic brackets showed improved protection for teeth bearing orthodontic appliances against acidic attacks.^[13] In this study, a bioglass paste was applied on enamel surfaces of teeth prior to bonding of orthodontic brackets in an attempt to use it as an orthodontic sealant. Previous study showed that the bond strength of orthodontic brackets to enamel treated with the same bioglass paste is within the clinically acceptable range;^[21] thus, it may be expected that premature debonding of orthodontic brackets is less likely to occur if bioglass is applied prior to bonding orthodontic bracket.

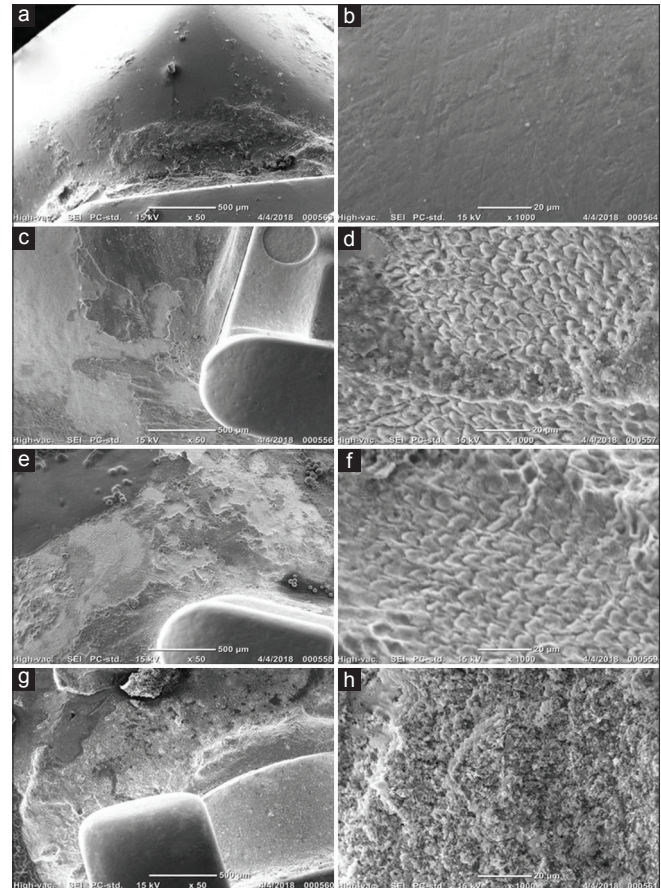


Figure 2: SEM observation for the top view of the specimens. Low (a) and high magnification; (b) top surface view for Control group (before erosion challenge) showing smooth enamel surface next to the orthodontic bracket. Low (c) and high (d) magnification for Control group (after erosion challenge) showing rough enamel surface with obvious boundaries of the enamel prisms. Low (e) and high (f) magnification for Fluoride group (after erosion challenge) showing rough enamel surface with obvious boundaries of the enamel prisms. Low (g) and high (h) magnification for Bioglass group (after erosion challenge) showing crystalline structures covering the areas next to the orthodontic bracket.

Erosive lesions are characterized by complete loss of enamel tissues and a concomitant subsurface demineralization.^[22] Topical fluoride application involves the release of large amounts of fluoride ions to the targeted enamel surfaces and modify it to fluorapatite crystals that was recorded to be of high resistance to dissolution in acids.^[23] This study showed that the

Table 1: Materials used in this study

Material (Manufacturer)	Composition
PALFIQUE Bond (Tokuyama Dental)	Phosphoric acid monomer, Bisphenol A di (2-hydroxy propoxy) dimethacrylate (Bis-GMA), Triethylene glycol dimethacrylate, 2-Hydroxyethyl methacrylate (HEMA), Camphorquinone, alcohol and purified water.
Transbond [®] MIP Moisture Insensitive Primer (3M Unitek)	Ethyl alcohol (30-40%) Bisphenol A diglycidyl ether dimethacrylate (15-25%) 2-Hydroxyethyl methacrylate (10%-20%) Copolymer of itaconic and acrylic acid (5%-15%) 2-Hydroxy-1,3-dimethacryloxypropane (5%-15%) Diurethanedimethacrylate (1%-10%) Water (1-10%)
Transbond PLUS color change adhesive (3M Unitek)	Silane Treated Glass, Silane Treated Quartz, Polyethylene glycol dimethacrylate, butanoic acid, 2- hydroxy-4-[[2-[(2-methyl-1-oxo-2- propen-1-yl) ox] ethyl] amino]-2-[2[[2- [(2-methyl-1-oxo-2-propen- 1yl) oxy] ethyl] amino]-2-oxoethyl]-4- oxo, Silane-treated silica, bisphenol - a diglycidyl ether dimethacrylate (Bisgma), diphenyliodonium Hexafluorophosphate.
Gelato APF Fluoride Gel (Keystone Industries)	Phosphoric acid (1%-5%), sodium fluoride (1%-3%)
45S5 Bioglass (NovaMin Technology)	SiO ₂ (46.1 mol%), CaO (26.9 mol%), Na ₂ O (24.4 mol%), P ₂ O ₅ (2.6 mol%)

Table 2: Weight percentage for each element detected by EDS

	Control	Fluoride	Bioglass
Carbon	25	25	21.5
Oxygen	53	53	40
Phosphorus	12	13	17
calcium	10	9	21
Silica	0	0	0.5

fluoride topical application for 5 min as recommended by manufacturer did not protect the enamel surface from the erosion challenge, which may be attributed to less capability of the acidic NaF 1% to adhere to the enamel surface when compared with other types of fluoride remineralizing agents.^[24]

Specimens which had 45S5 bioglass paste applied on them in this study showed resistance to the development of significant enamel erosive lesion which may be attributed to the formation of an interaction layer^[16,18,19,25,26] on top of enamel surface after the application of the 45S5 bioglass paste. Previous research showed that the aforementioned layer was resistant to abrasion^[16] suggesting the potential of forming a chemical bond between the enamel and the interaction layer.^[16] This study provided an additional advantage of the interaction layer as an acid resistant layer. The observed action of the agents utilized in this experiment is illustrated in Figure 3. The suggested mechanism of action for the 45S5 bioglass is illustrated in Figure 4 and can be summarized as follows: The 45S5 upon being mixed with phosphoric acid aqueous solution will rapidly release high amounts of calcium ions in addition to sodium ions, in the same time the hydroxide ions from the aqueous part of the solution will attack the silica network of the bioglass causing its breakdown and formation of

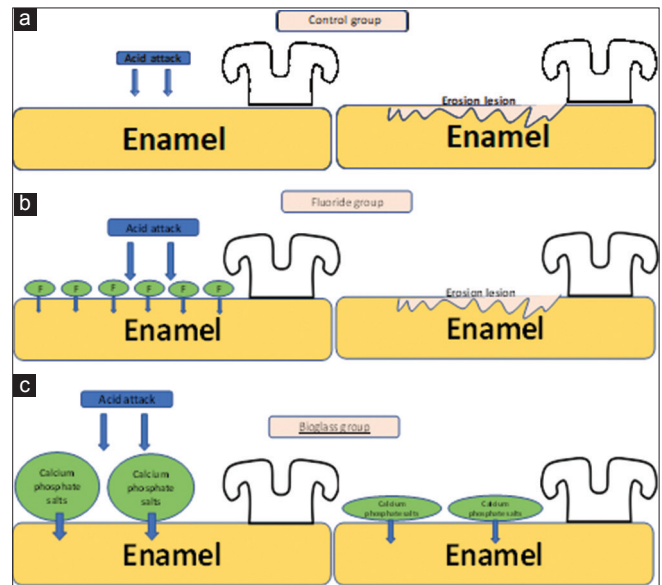


Figure 3: Suggested mechanism of action for the utilized materials. (a) Control group suffered erosion of the enamel surface next to the orthodontic bracket. (b) Fluoride was not able to protect the enamel surface next to the orthodontic bracket from erosion in the Fluoride group. (c) The bioglass paste formed a protective interaction layer that protected the enamel surface from erosion

silanol compounds.^[17,27] The silanol compounds are highly soluble in water,^[27] and thus, it is expected to be completely washed from the formed interaction layer upon washing it with strong water spray after 24 h as was demonstrated previously.^[16,18,19,25,26] The calcium ions released from the bioglass will combine with the phosphate ions released from the phosphoric acid solution to form calcium phosphate compounds that deposit on the enamel surface.^[16,18,19,25,26]

Previous study showed the biocompatibility of using the current technique of 45S5 bioglass application in direct contact with pulp cells, which may suggest its

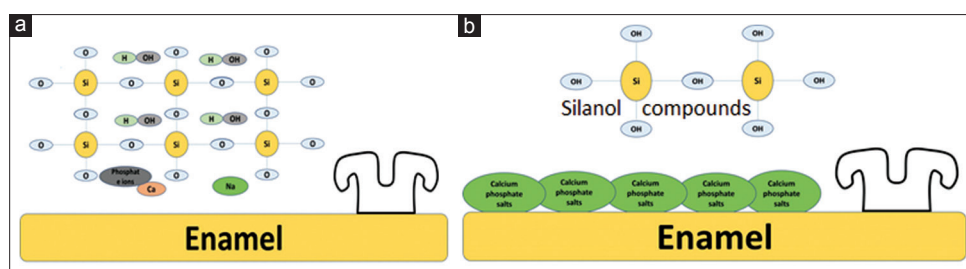


Figure 4: Mechanism of action for the 45S5 paste. (a) The 45S5 will rapidly release high amounts of calcium ions in addition to sodium ions, in the same time the hydroxide ions from the aqueous part of the solution will attack the silica network of the bioglass causing its breakdown and formation of silanol compound. (b) The silanol compounds will be formed and in the same time the calcium ions released from the bioglass will combine with the phosphate ions released from the phosphoric acid solution to form calcium phosphate compounds that deposit on the enamel surface

safe application on enamel surfaces.^[18] The application of the white bioglass paste resembles the application of temporary restorative material; thus, it is not expected to cause any esthetic problem during its application. Moreover, previous research showed that the interaction layer starts with the formation of microscopic layer of brushite crystals that will transform to hydroxyapatite within 14 days of storage in artificial saliva without being exposed to any acidic challenge.^[19]

It may be speculated that the application of the 45S5 bioglass with the current method prior to bonding of orthodontic brackets and keeping proper oral hygiene measures for orthodontic patients may be a good strategy capable of protecting the enamel surface from acidic attack.

Conclusion

45S5 Bioglass paste can form an interaction layer capable of protecting the enamel surface from erosive solution, suggesting its possible use as an orthodontic enamel sealer prior to bonding orthodontic brackets.

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Conflicts of interest

There are no conflicts of interest.

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