Are S-PRG Based Composites Able to Resist and Protect the Adjacent Enamel Against Erosive Wear?

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Research Article

Keywords: Dental Erosion, Tooth Wear, Dental Materials, S-PRG fillers, Giomer

Posted Date: June 1st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-550035/v1

Abstract

This in-vitro study evaluated the resistance of S-PRG-based-composites against erosive wear and their protective effect on enamel adjacent to restoration. Bovine-enamel-blocks were randomized into 12 groups (n=10/group), according to the factors material and type of wear (erosion-e or erosion+abrasion-a): S-PRG-based-composite-Beautifil II®(SPRGe/SPRGa); S-PRG-based bulk-fill-Beautifil Bulk Restorative®(SPRGBFe/SPRGBFa); composite-Filtek Z350 XT®(RCe/RCa); bulk-fill-composite-Filtek Bulk Fill®(BFe and BFa); glass-ionomer cement-EQUIA Forte®(GICe/GICa); resin-modified glass-ionomer cement-Riva®(RMGICe/RMGICa). Standardized cavities were prepared in specimens and restored. Initial profile was performed on the material and on the adjacent enamel at distances of 100/200/300/600 and 700µm. Specimens were immersed in 0.5%citric-acid (2min-6x/day-during 5days), and abrasive challenge was performed using a toothbrushing-machine (1min-after erosive challenge). Final profile was obtained following initial. Data were analyzed by two-way ANOVA and Tukey-test (α<0.05). On erosion, the GICe and RMGICe groups presented greater loss of material compared to other groups; up to 300µm away from the restoration, GICe and SPRGBFe were able to promote less enamel loss than composite groups. For erosion+abrasion S-PRG-based groups showed intermediate material wear compared to GICs (higher wear) and composites (less wear); there was no difference of enamel wear adjacent to restorations among groups. It is concluded that S-PRG-based-composites are a good alternative for restorative treatment of erosive tooth wear.

Clinical Significance: S-PRG-based composite restorations are able to diminish surrounding enamel erosive wear, similarly to glass ionomer cement, with the advantage of being more resistant to erosive challenge. Therefore, this material is a potential option to restore advanced erosion lesions in patients with etiological factors still present.

Introduction

Erosive tooth wear (ETW) corresponds to a tooth tissue destroy due to chemical-mechanical process, in which extrinsic (dietary) and intrinsic (gastric) acids interacts with attrition and/or abrasion [1]. The prevalence of this alteration is high and seems to be increasing [2–4]. The ideal treatment for ETW is based on early diagnoses and implementation of non-operative management strategies, acting on the risk factors for its development over time [5, 6]. When risk factors are not effectively controlled, the enamel, and eventually the dentine, is lost. According to the Radboud philosophy, even for patients who present severe tooth wear when there is no complaints, counselling and monitoring is the treatment of choice. Nevertheless, restorative treatment is recommended when there is loss of vertical dimension of occlusion, pain, and/or loss of esthetics. In these cases, minimally invasive and adhesive restorative strategies are indicated [7].

The longevity of restorative materials under erosive and abrasive challenges depends on durability of the material and durability of the interface between tooth substance and restoration [8, 9, 10]. In general, glass-ionomer cements (GIC) are more susceptible to wear than composites under chemical-mechanical challenges [11]. On the other hand, GICs are able to release fluoride, which could enhance the acid resistance of the tooth tissue adjacent to restorations [12, 13]. Therefore, there is no ideal material with potential benefits as resistance and preventive effects.

Giomer's technology is based on Surface Pre-Reacted Glass-ionomer (S-PRG) fillers that are synthesized by the reaction between fluoro-boro-aluminosilicate glass and a polyacrylic acid solution [14]. This material has shown to release multiple ions including F^-, Sr^{2+}, Na^+, BO_3^{3-}, Al^{3+}, and SiO_3^{2-} [15, 16]. The ions release promotes acid buffering action in the low pH lactic acid solution [17] and prevents demineralization around the material [18–23]. This filler is used in various dental materials including composite resins [24]. The buffering effect and the potential to prevent demineralization might be interesting characteristics of a material aiming to diminish the occurrence of enamel loss around restorations in patients with the presence of etiological factors for the development of erosive tooth wear. However, the evidence about the chemical mechanical resistance of this material or even its ability to prevent adjacent tooth tissue loss due to erosion is not clear yet. Therefore, this in vitro study aimed to evaluate the performance of S-PRG-based composite resins under erosion and abrasion and their influence on the adjacent enamel alteration. The null hypotheses formulated are that: 1) S-PRG-based composites are not resistant to erosive and abrasive challenges; and 2) S-PRG-based composites are not able to prevent enamel wear adjacent to the restoration, when subjected erosion or erosion and abrasion.

Material And Methods

Experimental Design

All experimental protocols were approved by the Research Ethics Committee of the Bauru School of Dentistry - University of São Paulo (FOB/USP) (protocol number 88429518.2.0000.5417), thereby, all research was performed in accordance with relevant guidelines/regulations.

The factors under study were type of material (six levels) and wear condition (two levels). One hundred and twenty crowns of bovine teeth composed the sample, the specimens were randomly assigned into 12 groups (n = 10 per group): S-PRG-based composite resin- Beautifil II® (SPRGe/SPRGa);S-PRG-based bulk-fill composite resin- Beautifil Bulk Restorative® (SPRGBFe/SPRGBFa); composite resin- Filtek Z350 XT® (CRe/CRa); bulk-fill composite resin- Filtek Bulk Fill® (BFe and BFa); glass-ionomer cement-EQUIA Forte® (GICe/GICa); resin-modified glass-ionomer cement-Riva® (RMGICe/RMGICe). Group followed by “e” was subjected to erosion and by “a” to erosion + abrasion.

Circular cavities were prepared on each specimen and then restored according to manufacturers’ instructions (Table 1). During 5 days, erosion was simulated in vitro (Groups e) by specimens’ immersion in 0.5% citric acid for 2 min, 6X/day. For groups subjected to erosion associated with abrasion (Groups a), each erosive challenge was followed by abrasion using a toothbrush machine with fluoridated dentifrice slurry (3:1) for 60 s. Between challenges, the blocks were kept in artificial saliva. The response variable was material and enamel loss measured by profilometry.

Specimen preparation

Approximately 140 bovine teeth were used in the present study. First the roots were separated from their crowns using a cutting machine (National Factory of Nevoni Single-phase Motors / Series 16.223, Type: TG1 / 3, São Paulo, SP) and a diaflex-F diamond disc (Wilcos do Brasil, Indústria e Comércio Ltda., Petrópolis, RJ). Crowns were individually placed in a cylindrical silicone mold (inner radius of 2.8 cm) and embedded in acrylic resin (Jet Ltd, Campo Limpo Paulista, SP, Brazil). Then, the specimens were ground flat with water-cooled silicon carbide discs (600, and 1200 grades of silicon carbide paper; Buehler Ltd, Lake Bluff, IL, USA) and polished with felt disc wet by 1 µm diamond spray (1 µm; Buehler Ltd., Lake Bluff, IL, USA). The enamel specimens were ultrasonicated (Ultrasonic Cleaner Mod USC 750, Unique Ind. And Com. Ltda, São Paulo, SP, Brazil) in deionized water for 2 min between the polishing steps.

One profile per specimen was performed to ascertain their planning and selecting 120 specimens. The profile was obtained with contact profilometer (Mahr Perthometer, Göttingen, Germany), coupled to a computer with a MarSurf XCR 20 contour software. Then, a random distribution was made using the Microsoft Excel program, using the "RANDOM" function of the mathematical category (10 specimens per group, 12 groups).

Circular cavities were prepared at the center of the crown using #2096 cylindrical diamond bur (KG Sorensen, São Paulo, SP, Brazil), with a diameter of 1.4 mm. A custom-made automatic device was used to standardize the depth of preparation (1.5 mm). For the composite with and without S-PRG fillers, 37% phosphoric acid and adhesive system were applied. Each material was handled according to the manufacturers’ instructions (Table 1). All restorative materials were inserted in a single increment and covered with polyester strip, followed by a glass slab kept under pressure to expel excess material from cavity.

Table 1
– Composition of each material and restoration’s instructions.

Material/Lot/Color	Group	Composition	Application Steps
Beautifil II® **Lot 051829 / Color A2**	S-PRG-based Composite Resin (SPRG)	Bis-GMA, TEGDMA, multifunctional filler, S-PRG filler based on F-Br-Al-Si glass	37% phosphoric acid* (15 sec), rinsing and drying, Universal Adhesive** (20 sec), drying (5 sec), light curing***, insertion of the material and light curing (40 sec).
Beautifil Bulk Restorative® **Lot 031828 / Color Universal**	S-PRG-based Bulk-Fill Resin (SPRGBF)	Bis-GMA, UDMA, Bis-MPEPP, TEGDMA, S-PRG based on F-Br-Al-Si glass	
Filtek One™ Bulk Fill® **Lot N963374 / Color A2**	Bulk-Fill Composite Resin (BF)	AFM, DDDMA, UDMA, AUDMA, pocrylat resins, ytterbium trifluoride, zirconia/ silica cluster	
Filtek™ Z350 XT® **Lot 1710900734 / Color A2 Dentin**	Composite Resin (CR)	Bis-GMA, Bis-EMA, UDMA, TEGDMA, zirconia/silica cluster and silica nanoparticle	
EQUIA Forte® **Lot 1709191**	Glass Ionomer Cement (GIC)	Powder: F-Al-Si glass, Polyacrylic acid powder, pigment. Liquid: Polyacrylic acid, distilled water, polybasic carboxylic acid	26% polyacrylic acid[#] (10 s), rinsing and drying, capsule agitation (10 s), material application, chemical polymerization (3 m), protector application[#] and polymarization (20 s).
RIVA Light Cure® / Lot J1602181EG	Resin-Modified Glass Ionomer Cement (RMGI)	Powder: F-Al-Si glass. Liquid: polyacrylic acid, HEMA and tartaric acid	26% polyacrylic acid[#] (10 s), rinsing and drying, capsule agitation (10 s), material application, light curing*** (20 s).

Abbreviations: Bis-GMA (bisphenol A-glycidyl methacrylate), TEGDMA (triethylene glycol dimethacrylate), F (fluoride), Br (boron), Al (aluminium), Si (silicate), UDMA (Urethane Dimethacrylate), Bis-MPEPP (Bisphenol-A polyethoxy-dimethacrylate), AFM (ddition-fragmentaion monomers), DDDMA (1,12-dodecanediol dimethacrylate), AUDMA (Aromatic urethane dimethacrylate), HEMA (2-hydroxyethyl methacrylate).

* Condac 37 FGM / Lot 1301317

** Adper Single Bond Universal 3M-ESPE / Lot 643238

*** Dabi Atlante / LED 1,400 mW / cm ^{2}

[##] Equia Forte Coat Protector (Lot 1702081)

[#] RIVA Conditioner / Lot 170705

After 7 days of storage at 37º C in 100% relative humidity, the restorations were polished with water-cooled silicon carbide discs as described before.

Initial Profilometric Analysis

Enamel blocks were marked with a scalpel blade (Embramac, Itapira, SP, Brazil) at two opposite sites with a distance of 0.3 mm from the margin of the restoration, resulting in two reference areas with 1.0 mm (at the border) and a test area with 2.0 mm, containing the restoration (at the center). Subsequently, initial surface profiles were obtained from the specimens using a profilometer (MarSurf GD 25, Göttingen, Germany) and contour software (MarSurf XCR 20). To standardize their position, specimens were fixed to a special holder and their locations were recorded allowing their exact replacement after the erosive-abrasive challenges. To analyze restorative material loss, two surface profiles were obtained through scanning from the reference to the test area, at the center of the restoration with a distance of 100 µm between them. On the other hand, to analyze enamel loss adjacent to restoration, five profiles were obtained through scanning from the reference to the test area, at 100–200 – 300–600 and 700 µm distant from the restoration margin.

Then, the previously demarcated reference areas were protected with cosmetic nail varnish (Colorama Maybelline - Ultra Dura, Cobra Cosméticos Ltda, São Paulo, SP, Brazil) to maintain its integrity during erosive and/or abrasive challenges.

In vitro erosive and abrasive challenges

All the specimens were subjected to six erosive cycling daily for 5 days, by their immersion in 30 ml of 0.5% citric acid pH 2.5 for 2 minutes under agitation at a speed of 50 rpm and at a controlled temperature of 25 ° C. After erosion, half of the specimens (erosion groups) were rinsed with deionized water for 5 s and kept immersed in artificial saliva (0.33g KH_2PO_4, 0.34g Na_2HPO_4, 1.27g KCl, 0.16g NaSCN, 0.58g NaCl, 0.17 g $CaCl_2$, 0.16 g NH_4 Cl, 0.2 g urea, 0.03 g glucose, 0.002 g ascorbic acid, pH 7 (KLIMEK et al., 1982 modified without mucin) [25], for 2 hours, until the next cycling. At the end of each day of cycling, the specimens were also immersed in artificial saliva, overnight (14 hours), under a temperature of 37°C.

For the groups in which erosion was associated with abrasion, toothbrush abrasion was performed after each erosive challenge, (6x / day for 5 days). Extra-soft toothbrushes (Colgate Twister®, Colgate Palmolive Industrial LTDA, S.B. Campo, SP, Brazil) were personalized for each specimen and fixed parallel to the dental surface on a brushing machine (Dental Biopdi, São Carlos, SP, Brazil). The dentifrice slurry was prepared daily by diluting fluoride dentifrice (Colgate triple action®, Colgate-Palmolive Industrial LTDA, SB Campo, SP, Brazil) in distilled water in the proportion 1: 3 (weight-volume ratio, according to ISO 14569 -1), and was always agitated before use. The slurry was automatic dropped on each specimen (≈ 3 ml). Each abrasive cycling consisted of brushing the specimens for 60 s with 100 reciprocal linear motion (back and forth) and force of 250 g, at temperature of 37.5°C. After abrasion, specimens were rinsed with deionized water for 5 s and kept immersed in artificial saliva similarly to erosion groups.

Profilometric Analysis

After the in vitro erosive and abrasive cycling, the cosmetic nail varnish was removed from the reference areas and the profilometric analysis was performed at the same sites of the initial measurements. Baseline and final profiles were perfectly matched, since the enamel specimens could be precisely repositioned in the profilometer wells. The material and enamel loss were quantitatively determined using a specific software (MarSurf XCR 20) by calculating the vertical difference (average depth of the surface) between baseline and final surface profiles. The material loss corresponded to the average value of the two profiles made at the center of the material (in micrometers). On the other hand, the enamel loss was analyzed in each evaluated distance from the restoration margin.

Statistical analysis

The assumptions of equality of variances and normal distribution of errors were satisfied. Two-way ANOVA and Tukey test were applied to analyze materials loss as well as the enamel loss in each distance in relation to the restoration. The significance level adopted was 5% and the software used was Sigma Plot for Windows (version 11.0, Erkrath, Germany).

Results

Table 2 shows the results for material loss. A statistic difference was found for type of material ($\alpha = 0.0001$), for condition ($\alpha = 0.0001$) and their interaction was also significant ($\alpha = 0.0001$). When considering the erosion condition, the composite groups (CRe, BFe) and the S-PRG-based groups (SPRGe, SPRGBFe) presented statistic similar material loss, which was less than that of the glass-ionomer cement groups (GICe, RMGICe). On the erosion + abrasion condition, the composite groups (CRa, BFa) presented less material loss, followed by S-PRG-based composite (SPRGa, SPRGBFa) and then by the glass-ionomer groups (GICa, RMGICa), with statistic difference among them. Considering each material, both glass-ionomers and both S-PRG-based composites showed higher material loss when erosion was associated with abrasion in comparison to erosion alone. The composite groups presented statistic similar material loss when subjected to erosion and erosion + abrasion conditions.

Table 2
Average wear on material (μm) and standard deviation (Sd) of the studied groups.

MATERIAL **CONDITION**	**Giomer** **Beautifil II®**	**Giomer - Beautifil Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	1.7 (± 0.7)^{a}	1.3 (± 1.0)^{a}	0.6 (± 0.4)^{a}	1.1 (± 0.8)^{a}	7.5 (± 4.6)^{b,c}	11.3 (± 5.5)^{c}
ERO + ABR	7.2 (± 1.6)^{b,c}	6.7 (± 2.9)^{b}	0.9 (± 0.7)^{a}	1.5 (± 0.8)^{a}	19.9 (± 3.0)^{d}	17.9 (± 4.7)^{d}

Different letters indicate statistical difference among group and conditions (two-way ANOVA and Tukey test).

ERO: erosion condition and ERO + ABR: erosion and abrasion condition.

Tables 3, 4, 5, 6 and 7 show the results for enamel loss at 100, 200, 300, 600 and 700 μm of distance from restoration margin, respectively. There was statistic difference for type of material, for condition and significant interaction on each distance. For erosion associated with abrasion condition, there was no statistic difference among materials in relation to enamel wear in all distances. When considering each material singly, the same behavior between conditions on studied distances were observed. All materials resulted in higher enamel loss when erosion was associated with abrasion compared to erosion alone, except CR (Z350 resin), which did not show any difference between the conditions (ERO and ERO + ABR). When considering only erosion, materials behavior was different on the studied enamel distances from the restoration margin.

At 100 μm, on erosion condition the SPRGBFe (Giomer Beautifil Bulk) and GICe (EQUIA) groups promoted less enamel wear than the CRe (Z350) and BFe (Bulk Fill), but were statisticaly similar to SPRGe (Giomer Beautifil II) and RMGICe (Riva LC), those 2 groups were also similar to CRe (Bulk Fill).

Table 3

Enamel wear (µm) and standard deviation (Sd) of the studied groups on the distance of 100 µm from the restoration margin.

MATERIAL **CONDITION**	**Giomer** **Beautiful II®**	**Giomer - Beautiful Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	30.3 (± 3.4)^{b,d}	28.3 (± 2.5)^{b}	38.3 (± 4.0)^{c,e}	35.6 (± 2.8)^{d,e}	27.7 (± 1.2)^{b}	31.4 (± 2.9)^{b,d}
ERO + ABR	44.1 (± 5.2)^{a,c}	44.6 (± 5.0)^{a}	43.2 (± 4.4)^{a,c}	47.1 (± 4.6)^{a}	43.7 (± 3.0)^{a,c}	47.3 (± 6.7)^{a}
Different letters indicate statistical difference (two-way ANOVA and Tukey test, α < 0.05)						
Material (α = 0.00002), condition (α = 0.0001) and significant interaction (α = 0.00007)						
ERO: erosion condition and ERO + ABRA: erosion and abrasion condition.						

At 200 µm of distance, considering erosion condition, both giomer-based composites (SPRGe-Beautifil and SPRGBFe-Beautifil Bulk) groups and conventional glass ionomer cement (GICe-EQUIA) group promoted statistic similar enamel loss, which was less when compared to composite resin (CRe-Z350) group. BFe group was statistic similar to S-PRG-based composite groups (SPRGe and SPRGBFe). RMGICe (Riva LC) was similar to both composite groups (CRe and BFe).

Table 4

Enamel wear (µm) and standard deviation (Sd) of the studied groups on the distance of 200 µm from the restoration margin.

MATERIAL **CONDITION**	**Giomer** **Beautiful II®**	**Giomer - Beautiful Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	30.6 (± 3.3)^{b,c}	29.4 (± 3.6)^{b,c}	38.2 (± 4.1)^{d,e}	35.0 (± 2.6)^{c,e}	27.9 (± 1.4)^{b}	32.1 (± 3.0)^{b,c,e}
ERO + ABR	44.2 (± 5.1)^{a,d}	45.5 (± 6.5)^{a}	44.0 (± 3.2)^{a,d}	47.1 (± 5.0)^{a}	43.9 (± 2.3)^{a,d}	47.0 (± 6.9)^{a}
Different letters indicate statistical difference (two-way ANOVA and Tukey test, α < 0.05)						
Material (α = 0.0002), condition (α = 0.0001) and significant interaction (α = 0.001)						
ERO: erosion condition and ERO + ABRA: erosion and abrasion condition.						

At 300 µm of distance, on erosion condition, only SPRGBFe (Giomer Beautifil Bulk) and GICe (EQUIA) groups resulted in less enamel wear than the RCe (Z350), but both were statistic similar to SPRGe, RMGICe and BFe (Giomer Beautifil II, Riva LC and Bulk Fill, respectively).

Table 5

Enamel wear (μm) and standard deviation (Sd) of the studied groups on the distance of 300 μm from the restoration margin.

MATERIAL **CONDITION**	**Giomer** **Beautiful II®**	**Giomer - Beautiful Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	30.9 (± 3.5)^{b,c}	29.7 (± 4.5)^{b}	37.8 (± 4.0)^{c,d,e}	34.4 (± 2.6)^{b,c,,e}	28.2 (± 1.4)^{b}	33.1 (± 2.2)^{b,c}
ERO + ABR	44.5 (± 4.7)^{a,d}	46.5 (± 11.3)^{a}	41.9 (± 4.6)^{a,d,e}	46.8 (± 4.7)^{a}	44.2 (± 2.0)^{a,d}	46.9 (± 8.1)^{a}
Different letters indicate statistical difference (two-way ANOVA and Tukey test, α < 0.05)						
Material (α = 0.07), condition (α = 0.0001) and significant interaction (α = 0.003)						
ERO: erosion condition and ERO + ABRA: erosion and abrasion condition.						

At 600 and 700 μm of distances, when considering erosion condition, there was no difference for enamel loss among the groups, except GICe (EQUIA) that resulted in less enamel loss compared to CRe (Z350).

Table 6

Enamel wear (μm) and standard deviation (Sd) of the studied groups on the distance of 600 μm from the restoration margin.

MATERIAL **CONDITION**	**Giomer** **Beautiful II®**	**Giomer - Beautiful Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	30.7 (± 3.2)^{b,c}	29.8 (± 4.1)^{b,c}	36.3 (± 3.7)^{c,d}	33.7 (± 2.6)^{b,c}	28.5 (± 1.4)^{b}	33.9 (± 2.4)^{b,c}
ERO + ABR	43.7 (± 4.8)^{a}	43.6 (± 7.3)^{a}	41.6 (± 4.5)^{a,d}	45.9 (± 4.3)^{a}	44.4 (± 2.3)^{a}	45.7 (± 7.5)^{a}
Different letters indicate statistical difference (two-way ANOVA and Tukey test, α < 0.05)						
Material (α = 0.03), condition (α = 0.0001) and significant interaction (α = 0.009)						
ERO: erosion condition and ERO + ABRA: erosion and abrasion condition.						

Table 7
Enamel wear (µm) and standard deviation (dp) of the studied groups on the distance of 700 µm from the restoration margin.

MATERIAL CONDITION	**Giomer Beautiful II®**	**Giomer - Beautiful Bulk Restorative®**	**Z350 XT® Resin**	**Bulk Fill Resin**	**EQUIA Forte®**	**RIVA LC®**
ERO	30.4 (± 2.8)^{b,c}	30.0 (± 3.6)^{b,c}	36.1 (± 3.5)^{c,d}	33.3 (± 2.2)^{b,c}	29.0 (± 1.6)^{b}	34.2 (± 2.4)^{b,c}
ERO + ABR	43.7 (± 4.2)^{a}	43.2 (± 8.2)^{a}	41.3 (± 3.9)^{a,d}	45.3 (± 5.0)^{a}	44.6 (± 2.4)^{a}	45.3 (± 6.9)^{a}
Different letters indicate statistical difference (two-way ANOVA and Tukey test, α < 0.05)						
Material (α = 0.08), condition (α = 0.0001) and significant interaction (α = 0.008)						
ERO: erosion condition and ERO + ABRA: erosion and abrasion condition.						

Discussion

Many restorative materials have been tested regarding their resistance to erosive tooth wear [11, 13, 19, 22, 26, 27]. When restorative treatment is indicated for patients who present erosive tooth wear, the ideal management is the association with measures that eliminate the causes of erosive wear [5–8]. However, this approach is not always feasible, implying that the use of bioactive materials capable of protecting the adjacent tooth structure is highly desirable. The results of the present study showed that the S-PRG-based composite materials were able to promote less enamel loss located at 100 µm distant from restoration margin, when compared to resin composite, therefore, the second formulated null hypothesis was rejected. The S-PRG-based bulk-fill composite resin (SPRGBFe- Beautifil bulk fill) promoted a reduction of 26% of enamel wear, which was similar to conventional glass-ionomer (GICe- EQUIA), with a 27% reduction. The reference for calculating the enamel loss reduction was composite resin group (Z350), as this material was the less effective material to protect against erosive wear, and the amount of enamel loss of this group was considered as 100%. This reduction was statistically significant up to 200 µm for SPRGBFe and on all distances for GICe. Therefore the protective effect on adjacent enamel against erosion, promoted by S-PRG-based composite groups was notable. Although restricted to enamel very close to the material, it might not be ignored, since the frequent acid exposure may affect the margins of the adhesive restorations, favoring the flow of fluids through the adhesive interface [28].

Previous in vitro and in situ studies did not find difference on the prevention of enamel loss adjacent to different types of materials (amalgam, composite resin and glass-ionomer cement) by means of profilometry and hardness [19, 27]. The explanation for the contradictory results, compared to the present study can be the profile measurement method, materials composition and the erosive protocol. On these studies, the profile reached around 1.5 mm distance from the material [19], probably not showing their potential protective effect, which was shown to be higher in the margins, in our study. On the other hand, some studies also found less enamel loss adjacent to glass-ionomer cements [12, 13]. Rolim et al. 2012, evaluated the percentage of mineral loss on the surface around restorations under the use of highly fluoridated dentifrices and showed that teeth restored with conventional GIC provided an additional protection against enamel erosion regardless of dentifrice used [12]. Similarly, Alghilan et al. investigated the effect of erosion on restorative materials and on adjacent enamel, simulating different salivary flow rates, and found that fluoride-containing materials promoted less loss of enamel surface under erosive challenges [13]. Although there is no agreement on the protective ability of the glass-ionomer cement regarding adjacent enamel under erosive challenges [19, 29], the present study found the best effect for CGIe. However, the modified glass-ionomer (RMGIe) resulted in similar enamel wear compared to composite resin group (CRe-Z350) and it was expected a better performance. In contrast, another study found that resin-modified glass ionomer cement (Fuji II LC) was the only material able to protect the enamel adjacent to the restorations against the erosive and erosive-abrasive challenges [30]. This result reinforces the knowledge that significant variation can exist among materials within the same category, depending on factors such as the nature, size of the filler particles [11] and the presence of resin. Resin modified glass ionomer cement in general exhibit a short-term fluoride release which is lower and takes more time as compared with the conventional cements [31], this characteristic might have decreased the ability to protect the adjacent enamel against erosive challenge.

The protective effect found for S-PRG-based composite groups (SPRGe and SPRGBFe) was similar to glass-ionomer cement groups (GICe and RMGIe). We hypothesize that fluoro-alumina-boro silicate glass filler (S-PRG) can release Silicon, Strontium, Aluminum, Boron, Sodium, and Fluoride ions, neutralizing the erosive acids and reducing enamel demineralization [29]. Nedeljkovic et al. 2016 found that Beautifil II was capable of increasing the pH of the solutions up to neutral (6 to 7) and attributed this ability to the S-PRG fillers [32]. Strontium presents a synergistic effect when applied in association with Fluoride, with an advantageous of replacing hydroxyl and calcium ions in the apatite structure [33], this results in a more acid-resistant strontium and fluoride-modified apatite that may be less soluble under acid exposure. However, in the study of Viana et al. 2020 -PRG-based composite (Beautifil II) was not able to protect adjacent enamel against erosion [30].

When abrasion was conducted after erosion, no protective effect was observed for the studied materials. Probably the ions released by the S-PRG-based composite groups and the fluoride by the glass-ionomer cement groups did not increase enamel mechanical resistance sufficiently to reharden the softened enamel and reduce its loss due to abrasion. Even highly concentrated polyvalent metal fluorides present limitation on the protective effect because the mechanical impact overcomes their chemical beneficial effect [34].

Regarding the material loss due to acid attack, the composite groups showed the lowest wear. This result is in accordance with previous studies [11, 35] and can be explained mainly by the low acid-degradation of the composite matrix organic content [11, 36]. In the composite groups, we did not find statistic difference between wear conditions, since material wear of erosion alone was similar to erosion +

abrasion. The mechanical resistance of the composite matrix in addition to bond stability between the filler and the matrix increases the abrasion resistance of the composite-based restorative materials [36].

Glass-ionomer cements showed the highest loss, which is in line with the literature [11, 34]. Previous studies explain these results by the acid ability to dissolve the siliceous hydrogel layer, resulting in peripheral matrix dissolution and exposure the glass particles [26, 37, 38]. Since the dissolution of this matrix causes a softening of the material, it is easily removed by toothbrush abrasion as we can see on the present results (Table 1) and in the study conducted by Yu et al. [26]. It was expected that conventional Glass-ionomer cements would present significant higher loss due to erosion than resin-modified ones; however, in the present study it was observed the opposite.

The S-PRG-based composite groups showed similar wear compared to the composite groups which is in line with previous study [30]. The first formulated null hypothesis was rejected. This result can be attributed to the presence of bis-GMA and TEGDMA matrix, which is resistant to acid [24] and to high filler content. Contrary to the present study, Kooi et al. 2012, demonstrated that the Giomer's (resin composite with S-PRG fillers) hardness and roughness are more affected than composite resins by citric acid, due to the fluoroborosilicate glass fillers greater susceptibility to degradation by weak acids than the zirconia-silicate filler of the conventional composite. [24]. For erosion + abrasion, S-PRG-based composite resins showed intermediate material wear compared to GIC (higher wear) and composite resins (less wear). Composites with nanofillers particles exhibit homogeneous and less prominent particles on the surface, which are less susceptible to removal by mechanical forces [24]. Probably fluorosilicate glass fillers are more superficial and prominent to promote ions release, but this characteristic might also facilitate their removal.

Given the limitations of this in vitro study, S-PRG-based composite resins have showed to be a potential alternative for the restorative treatment of patient with erosive tooth wear, due to their higher resistance to erosive and/or abrasive wear than glass-ionomer cements, and their effective protection of enamel near to the restoration.

Conclusion

When the restoration was subjected solely to erosion challenge, S-PRG-based composite resins in similar performance to conventional composites, was less susceptible when compared to glass-ionomer cement. In addition, they S-PRG -based composite resins promoted a reduction in enamel wear surround the margin of restoration, which was also observed when conventional glass-ionomer was used. None of the studied materials were able to protect enamel adjacent to restoration when erosion was associated with abrasion and this challenge resulted in intermediate loss of S-PRG -based composites compared to glass-ionomer cement, which showed the highest wear while composite resins were less prone to wear.

Declarations

Acknowledgements

The authors would like to gratefully acknowledge the financial support from CAPES (processes number 001).

Competing interests

The authors declare no competing interests.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

References

1. Schlueter, N. *et al.* Terminology of Erosive Tooth Wear: Consensus Report of a Workshop Organized by the ORCA and the Cariology Research Group of the IADR. *Caries Res.* **54**, 2–6 (2020).
2. Tschammler, C., Müller-Pflanz, C., Attin, T., Müller, J. & Wiegand, A. Prevalence and risk factors of erosive tooth wear in 3–6 year old German kindergarten children-A comparison between 2004/05 and 2014/15. *J. Dent.* **52**, 45–49 https://doi.org/10.1016/j.jdent.2016.07.003 (2016).
3. Salas, M. M. S., Nascimento, G. G., Huysmans, M. C. & Demarco, F. F. Estimated prevalence of erosive tooth wear in permanent teeth of children and adolescents: an epidemiological systematic review and meta-regression analysis. *J. Dent.* **43**, 42–50 (2015).
4. Brusius, C. D., Alves, L. S., Susin, C. & Maltz, M. Dental erosion among South Brazilian adolescents: A 2.5-year longitudinal study. *Community Dent. Oral. Epidemiol.* **46**, 17–23 (2018).
5. Carvalho, J. C., Scaramucci, T., Aimée, N. R., Mestrinho, H. D. & Hara, A. T. Early diagnosis and daily practice management of erosive tooth wear lesions. *Br. Dent J.* **224**, 311–318 (2018).
6. Buzalaf, M. A. R., Magalhães, A. C. & Rios, D. Prevention of erosive tooth wear: targeting nutritional and patient-related risks factors. *Br. Dent. J.* **224**, 371–378 (2018).
7. Loomans, B. & Opdam, N. A guide to managing tooth wear: the Radboud philosophy. *Br. Dent. J.* **224**, 348–356 (2018).
8. Peutzfeldt, A., Jaeggi, T. & Lussi, A. Restorative therapy of erosive lesions. *Monogr. Oral. Sci.* **25**, 253–261 (2014).
9. Wang, L. *et al.* Effect of simulated intraoral erosion and/or abrasion effects on etch-and-rinse bonding to enamel. *Am. J. Dent.* **27**, 29–34 (2014).
10. Casas-Apayco, L. C. *et al.* Erosive cola-based drinks affect the bonding to enamel surface: an in vitro study. *J. Appl. Oral. Sci.* **22**, 434–441 (2014).

11. Shabanian, M. & Richards, L. C. In vitro wear rates of materials under different loads and varying pH. *J. Prosthet. Dent.* **87**, 650–656 (2002).
12. Rolim, F. G., Sá, A. F., Silva-Filho, G. W. L., Brandim, A. D. S. & Vale, G. C. Effect of High-Fluoride Dentifrice on Enamel Erosion Adjacent to Restorations In Vitro. *Oper. Dent.* **41**, 157–161 (2016).
13. Alghilan, M. A., Cook, N. B., Platt, J. A., Eckert, G. J. & Hara, A. T. Susceptibility of restorations and adjacent enamel/dentine to erosion under different salivary flow conditions. *J. Dent.* **43**, 1476–1482 (2015).
14. Ikemura, K. *et al.* Optimizing filler content in an adhesive system containing pre-reacted glass-ionomer fllers. *Dent. Mater.* **19**, 137–146 (2003).
15. Han, L. & Okiji, T. Evaluation of the ions release / incorporation of the prototype S-PRG filler-containing endodontic sealer. *Dent. Mater. J.* **30**, 898–903 (2011).
16. Shimazu, K., Ogata, K. & Karibe, H. Evaluation of the ionreleasing and recharging abilities of a resin-based fissure sealant containing S-PRG filler. *Dent. Mater. J.* **30**, 923–927 (2011).
17. Kaga, N. *et al.* Inhibition of enamel demineralization by an ion-releasing tooth-coating material. *Am. J. Dent.* **32**, 27–30 (2019).
18. Alsayed, E. Z. *et al.* Effects of coating materials on nanoindentation hardness of enamel and adjacent areas. *Dent. Mater.* **32**, 807–816 (2016).
19. Rios, D. *et al.* In situ effect of an erosive challenge on different restorative materials and on enamel adjacent to these materials. *J. Dent.* **36**, 152–157 (2008).
20. Tyras, M. J. Cariostatic effect of glass ionomer cement: a five-year clinical study. *Aust. Dent. J.* **36**, 236–239 (1991).
21. Forsten, L. Clinical experience with glass ionomer for proximal fillings. *Acta. Odontol. Scand.* **51**, 195–200 (1993).
22. Honório, H. M. *et al.* Effect of prolonged erosive pH cycling on different restorative materials. *J. Oral. Rehabil.* **35**, 947–953 (2008).
23. Yoneda, M., Suzuki, N. & Hirofuji, T. Antibacterial effect of surface pre-reacted glass ionomer filler and eluate–mini review. *Pharm. Ana.l Acta.* **6**, 349 (2015).
24. Kooi, T. J. M. *et al.* Effects of food-simulating liquids on surface properties of giomer restoratives. *Oper. Dent.* **37**, 665–671 (2012).
25. Klimek, J., Hellwig, E. & Ahrens, G. Effect of plaque on fluoride stability in the enamel after amine fluoride application in the artificial mouth. *Dtsch. Zahnarztl. Z.* **37**, 836–840 (1982).
26. Yu, H. *et al.* Erosion and abrasion of tooth-colored restorative materials and human enamel. *J. Dent.* **37**, 913–922 (2009).
27. Zanatta, R. F. *et al.* Microleakage and shear bond strength of composite restorations under cycling conditions. *Oper. Dent.* **42**, E71–E80 (2017).
28. Francisconi, L. F. *et al.* Effect of Erosive pH cycling on Different Restorative Materials and on Enamel Restored with These Materials. *Oper. Dent.* **33**, 203–208 (2008).

29. Kaga, M. *et al.* Inhibition of enamel demineralization by buffering effect of S-PRG fillercontaining dental sealant. *Eur. J. Oral. Sci.* **122**, 78–83 (2014).
30. Viana, Ã. *et al.* Bioactive Materials Subjected to Erosion/Abrasion and Their Influence on Dental Tissues. *Oper. Dent.* **45**, E114–E123 (2020).
31. De Witte, A. M., De Maeyer, E. A., Verbeeck, R. M. & Martens, L. C. Fluoride release profiles of mature restorative glass ionomer cements after fluoride application. *Biomaterials.* **21**, 475–482 (2000).
32. Nedeljkovic, I. *et al.* Lack of buffering by composites promotes shift to more cariogenic bacteria. *J. Dent. Res.* **95**, 875–881 (2016).
33. Thuy, T. T. *et al.* Effect of strontium in combination with fluoride on enamel remineralization in vitro. *Arch. Oral. Biol.* **53**, 1017–1022 (2008).
34. Huysmans, M. C., Young, A. & Ganss, C. The role of Fluoride in Erosion Therapy. *Monogr. Oral. Sci.* **25**, 230–243 (2014).
35. Aliping-McKenzie, M., Linden, R. W. A. & Nicholson, J. W. The effect of Coca-Cola and fruit juices on the surface hardness of glass–ionomers and 'compomers'. *J. Oral Rehabil.* **31**, 1046–1052 (2004).
36. Zimmerli, B., Strub, M., Jeger, F., Stadler, O. & Lussi A.Composite materials: Composition, properties and clinical applications A Literature Review. *Schweiz. Monatsschr. Zahnmed.* **120**, 972–986 (2010).
37. El-Badrawy, W. A. & McComb, D. Effect of home-use fluoride gels on resin-modified glass-ionomer cements. *Oper. Dent.* **23**, 2–9 (1998).
38. Turssi, C. P., Hara, A. T., Serra, M. C. & Rodrigues, A. L. Jr Effect of storage media upon the surface micromorphology of resin-based restorative materials. *J. Oral. Rehabil.* **29**, 864–871 (2002).