Influence of fluoride-releasing materials in the inhibition of enamel and dentin demineralization around restorations

Influência de materiais liberadores de flúor na inibição da desmineralização do esmalte e da dentina ao redor de restaurações

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ABSTRACT

Objective: The aim was to evaluate the influence of fluoride-releasing restorative materials in enamel and dentin microhardness. **Material and Methods:** 40 blocks (5x5x3 mm) from cervical third of human molars received a cavity preparation between the enamel and dentin, and the restorations were subjected to *in vitro* caries model. Specimens were randomly restored with (n=10): conventional glass ionomer cement (Ketac Cem, 3M ESPE); polyacid-modified composite resin (Ionoseal, VOCO); resin-modified glass ionomer cement (Ionofast, Biodinâmica); or microhybrid composite resin (Filtek Z250, 3M ESPE). The specimens were sectioned longitudinally and enamel and dentin Knoop microhardness were determined at different distances from the restorative material (100, 200 and 300 μm) and depth of surface (20, 40 and 60 μm). The data were submitted to three-way repeated measures ANOVA and Tukey´s test (α=0.05). **Results:** For enamel, the double interactions between material x distance and material x depth were statistically significant. In all depths and distances, the highest values of enamel microhardness were observed for Ketac Cem. In dentin, the materials differed statistically from each other, and Ionoseal obtained higher microhardness values than those found in Ionofast. **Conclusion:** Conventional glass ionomer cement is more effective in preventing enamel demineralization around restoration followed by the polyacid-modified composite resin. In dentin, the polyacid-modified composite resin obtained better performance than resin-modified glass ionomer cement.

KEYWORDS

Compomers; Dental caries; Glass ionomer cements; Hardness tests; Composite Resins.

RESUMO

Objetivo: O objetivo foi avaliar a influência de materiais restauradores liberadores de flúor na microdureza do esmalte e da dentina. **Material e Métodos:** 40 blocos (5x5x3 mm) do terço cervical de molares humanos receberam preparo cavitário entre esmalte e dentina, e após a restauração foram submetidas a um modelo *in vitro* de cárie. As amostras foram restauradas aleatoriamente com (n=10): cimento de ionômero de vidro convencional (Ketac Cem, 3M ESPE); resina composta modificada por poliácidos (Ionoseal, VOCO); cimento de ionômero de vidro modificado por resina (Ionofast, Biodinâmica); ou resina composta microhíbrida (Filtek Z250, 3M ESPE). As amostras foram seccionadas longitudinalmente e a microdureza Knoop de esmalte e dentina foi determinada em diferentes distâncias do material restaurador (100, 200 e 300 μm) e profundidade de superfície (20, 40 e 60 μm). Os dados foram submetidos à ANOVA para medidas repetidas de três fatores e teste de Tukey (α=0,05). **Resultados:** Para o esmalte, as duplas interações entre material x distância e material x profundidade foram estatisticamente significativas. Em todas as profundidades e distâncias, os maiores valores de microdureza do esmalte foram observados para o Ketac Cem. Na dentina, Ionoseal obteve valores de microdureza superiores aos encontrados no Ionofast. **Conclusão:** O cimento de ionômero de vidro convencional é mais eficaz na prevenção da desmineralização do esmalte ao redor da restauração, seguido pela resina composta modificada por poliácidos. Na dentina, a resina composta modificada por poliácidos obteve melhor desempenho que o cimento de ionômero de vidro modificado por resina.

PALAVRAS-CHAVE

Compômeros; Cárie dentária; Cimentos de ionômeros de vidro; Testes de Dureza; Resinas Compostas.

INTRODUCTION

Secondary caries is still a challenging subject in dentistry and can be defined as a carious lesion developed around a preexisting restoration. Secondary caries has been considered a common reason for replacing a restoration [1,2], reaching up to 60% of all caries lesions found that demonstrates the need to develop and study new materials [3-6]. The restorations failure is mainly attributed to secondary caries [7,8] because the enamel or dentin margins immediately adjacent to the restorations or the restoration interface are regions where the accumulation of biofilm and the development of caries lesions is easier, especially if there are marginal flaws, porosities, and inadequate adaptation [9-11].

The adhered biofilm consists of multiple bacterial species and their organic products, able to produce acids that cannot be sufficiently buffered by saliva. As the pH decreases, the balance between demineralization and remineralization of the tooth structure is disrupted and leaching of calcium and phosphate ions occurs. In contrast to the external surfaces of the tooth, from which the biofilm can be removed through daily oral hygiene, the gap between the tooth and the restoration is inaccessible to mechanical cleaning. This allows the free development of bacteria within this space, eventually leading to secondary caries [10,12].

Fluoride-releasing restorative materials have been developed because the fluoride released from these materials could reduce the effects of demineralizing events, likewise, enhance tooth remineralization [11,12]. The presence of fluoride in the composition of the glass ionomer (or other materials) is clinically favorable, since fluoride ions are released and exchanged promptly with hydroxyl hydroxyapatite ions, providing an anti-caries effect [12-15]. Glass ionomer cements (GIC) have some mechanical and clinical limitations, such as prolonged gelling reaction time, dehydration or initial excess moisture, low resistance to tension and compression and aesthetic problems due to their limited translucency. Thus, monomeric components such as bisphenol-A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA) and 2-hydroxyethyl methacrylate (HEMA) were added to the conventional ionomer composition, resulting in resin-modified glass ionomer cement (RMGIC) and polyacid-modified composite resin (PMCR) or compomers. In this sense, there are advantage of RMGIC over conventional GIC as a better seal of the tooth/restoration interface [3,12,16].

The tooth preparation for caries restorative treatment could result in interproximal cavities (Class II) that extends close or apically to dentin margins. In some cases, the GIC could is placed at the base of the cavity preparation, followed by restoration in composite resin to finish the treatment without external exposure of GIC ("sandwich technique"). In other cases, the GIC is exposed to the oral environment at the base of the restoration, this management is commonly denominate an "open-sandwich technique" [17,18]. These techniques were suggested to limit the deficiencies of composite resins in posterior restorations, particularly the lack of permanent adhesion to dentin, post-operative sensitivity, and the development of secondary caries [18-20]. However, there is a lack of studies evaluating the dynamics of remineralizing-demineralizing processes according to the material or technique used, especially considering the need for more conservative clinical approaches.

The association of other materials with composite resins during tooth restoration can allows to improve the clinical performance, making the restorative procedure simpler and longer lasting [19,21]. Thus, the objective of this study was to evaluate the performance of fluoride-releasing restorative materials in inhibiting or decreasing the demineralization of enamel and dentin margins. The null hypothesis was that there would be no difference in the microhardness of enamel or dentin around restorations for the evaluated materials after the pH-cycling model.

MATERIAL AND METHODS

Specimen preparation

After approval by the Local Research Ethics Committee (CAAE: 14127019000005374) third molars were acquired from patients/volunteers who signed an informed consent. Thus, human third molars without coronal cracks or malformations were stored in 0.1% thymol and submitted to debridement with scalpel blades and periodontal curettes. The cervical portions of the

buccal and palatal/lingual surfaces of the teeth were used, totaling 40 blocks.

The third molars were longitudinally sectioned to separate the buccal surface from the palatal/lingual surfaces using a low-speed water-cooled diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA). Thus, the half of the tooth was sectioned again to acquire a dental block from the cervical portion, measuring 5 x 5 mm by 3 mm in thickness. A digital caliper (Mitutoyo Corporation, Kawasaki, Japan) was used to verify these measurements. The preparations measuring 2 mm in diameter and 2 mm in deep were made with a standardized flat cylindrical diamond tip (#2292, KG Sorensen, Barueri, SP, Brazil) with a stop apparatus to control the deep, at high speed and under cooling with spray of distilled water on tooth surfaces. Considering the cervical portion of tooth, the preparation margins closer occlusal was in enamel and cervical in dentin.

Group division

The prepared specimens were separated into four groups (n=10) using a simple randomization, according to the restorative material: conventional glass ionomer cement (Ketac Cem, 3M ESPE, Deutschland); polyacid-modified composite resin (Ionoseal, VOCO, Cuxhaven, Germany); resin-modified glass ionomer cement (Ionofast, Biodinâmica, Paraná,

Brazil); and microhybrid composite resin (Filtek Z250, 3M ESPE, Minnesota, USA) with adhesive system (Adper Single Bond 2, 3M ESPE). The Table I presents general information about the materials used in the study. The restorations were restricted to the cavity walls and limited to the cavosurface angle.

In the group in which the cavity was restored with composite resin, the 2-step total-etch adhesive (Adper Single Bond 2) was used according to the manufacturer's recommendations (Table I). The light-cured materials were photoactivated for 20 s with an LED curing light (Valo, Ultradent, Utah, USA), in standard mode (1000 mW/cm^2).

pH-cycling model

To verify the effects of restorative materials on the inhibition of demineralization around the enamel-dentin/restoration interface, a pH-cycling model was used to induce the development of caries-like lesions. Restored blocks were sealed with three layers of nail polish (Colorama, Procisa Produtos de Beleza Ltda, São Paulo, SP, Brazil), except for 1 mm in diameter around the restoration margins. The adhesive paper (4 mm, Contacto, Rio de Janeiro, Brazil) was placed over the restoration to prevent the application of nail polish on the dental margins, where the pH-cycling challenge was produced [22,23].

Table I - Classification, manufacturers, composition, and instructions of the materials

Material/Manufacturer	Composition	Instructions
Conventional Glass Ionomer. Ketac Cem Easymix (3M ESPE). Lot number: 1911600623	Powder: Glass powder, pigments, polycarboxylic acid. Liquid: tartaric acid, water, preservatives.	Manipulate 1 amount of the powder into two drops of the liquid and apply the material in a viscous consistency to the bottom of the clean cavity.
Polyacid-modified composite resin Ionoseal (VOCO) Lot number: 1845144	BIS-GMA; BIS-DMA, DUDMA, HEDMA, aluminum, barium, sodium, calcium, fluoride, glass phosphorosilicate.	Apply the material directly from the syringe into clean cavity. Light curing every 1 mm of thickness.
Resin-modified glass ionomer cement Ionofast (Biodinâmica) Lot number: 28718	Glass of calcium fluorosilicate, barium and aluminum; methacrylic monomers; silicon dioxide; catalyst; stabilizer; pigments.	Apply the material directly from the syringe into clean cavity. Light curing every 1 mm of thickness.
Microhybrid composite resin Filtek Z250 (3M ESPE) Lot number:1816300690	Bis-GMA, Bis-EMA, UDMA, zirconia/silica particles	Incrementally insert 2 mm thick layers and light cure for 20 s.
2-step total-etch adhesive Adper Single Bond 2 (3M ESPE) Lot number: 1901700234	Bis-GMA, HEMA, ethanol, water, dimethacrylates, initiators, polyalkenoic acid copolymer, silica nanofiller.	Apply 2 layers of the adhesive for 15s, dry gently for 5s and light cure for 10s.
Phosphoric acid Ultra-etch (Ultradent) Lot number: D00XQ	35% orthophosphoric acid, thickener, dye and deionized water.	With clean dental surfaces, apply the gel and leave 20 s on the enamel and 10s on the dentin. After this, rinse with water for 20 s.

Legends: Bis-GMA, bisphenol A-glycidyl methacrylate; BIS-DMA, bisphenol A dimethacrylate; DUDMA, Diurethane dimethacrylate; HEDMA, 2-hydroxyethyl dimethacrylate; Bis-EMA, Bisphenol-A dimethacrylate ethoxylate; UDMA, urethane dimethacrylate; HEMA, hydroxyethyl methacrylate.

The specimens were submitted during 14 days to daily cycles of exposure to demineralizing (6 hours per day) and remineralizing solution (18 hours per day). The demineralizing solution is composed by 2 mM calcium, 2 mM phosphorus, and 0.075 M acetate buffer, set pH = 4.3. The remineralizing solution contained 1.5 mM calcium, 0.9 mM phosphorus, 0.15 M potassium chloride, set pH = 7. The solutions were renewed every day, and the specimens were washed with distilled water in each solution change [24]. During the experiment the specimens were stored at 37 °C.

Microhardness assessment

After the pH-cycling, the blocks were sectioned longitudinally in the center of the restoration, using a precision cutter and high concentration diamond disc (Isomet 1000, Buehler Ltd., Lake Bluff, IL, USA). The cut fragments were embedded in epoxy resin (Varidur, Düsseldorf, Germany) and polished (Buehler Ltd., LakeBluff, IL, USA) to obtain smooth surfaces for microhardness tests with aluminum abrasive paper (#600 and #1200) and with diamond paste (Alpha Micropolish, kBuehler Ltd., Lake Bluff, IL, USA). Then, the blocks were washed in deionized water to remove any residue from the polishing process.

The Knoop microhardness was assessed in a digital microhardness tester (HVS 1000, PanTec, SP, Brazil) with 10g load for 5s. Microhardness measurements were made on enamel and dentin with standardized distances (100, 200 and 300 μm) from the restoration interface on enamel and dentin; and the depth of 20, 40 and 60 μm from the enamel or dentin surface. As described in a previous investigation [24], Figure 1 presents the locations of microhardness indentations in the present study.

Statistical analysis

The microhardness values measured in the enamel and dentin were checked for normal distribution and homoscedasticity. Thus, square root transformation was applied to enamel results for contemplate requisites to parametric statistical evaluation. The effect of the restorative material on the different distances and depths of the enamel and dentin was investigated through three-way repeated measures ANOVA and Tukey´s test. For statistical calculations, a
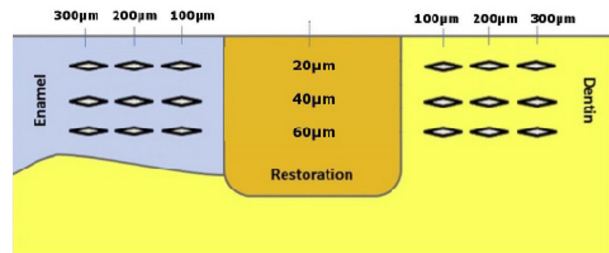

Figure 1 - Locations of microhardness indentations according to described by Bridi et al. [24].

significance level of 5% was established and the SPSS 23 program (SPSS Inc., Chicago, IL, USA) was used.

RESULTS

Microhardness results

Table II summarizes the descriptive analysis of the microhardness values associated with the use of each restorative material, in the different distances (100, 200 and 300 μm) and depths (20, 40 and 60 μm) of the enamel and dentin. For the enamel microhardness, the three-way repeated measures ANOVA demonstrated that there was no statistically significant interaction for restorative material, distance, and depth ($P = 0.271$). Moreover, the double interactions between the restorative material and distance ($P = 0.001$) and between the restorative material and the depth ($P < 0.001$) were both statistically significant.

Figure 2A shows a line diagram considering the interaction between the restorative material and the distance of restoration in enamel. At 100 and 200 μm, the enamel adjacent to the Ketac Cem presented significantly greater microhardness than Ionoseal material, which, for in turn, the enamel had a higher microhardness than that provided by Ionofast. At any of the distances, the lowest microhardness values were obtained by composite resin (Filtek Z250). The difference between the materials (Ionoseal, Ionofast and Filtek Z250) was no longer statistically significant at 300 μm, while the microhardness provided by Ketac Cem cement remained significantly higher. Figure 2B presents a line diagram considering the interaction between the restorative material and the depth of enamel surface. At a depth of 20 μm, there was no statistically significant difference between the Ketac Cem and Ionoseal, which were associated

Table II - Mean (standard deviation) of Knoop microhardness (Kg/mm²) at different distances and depths of enamel and dentin adjacent to restorative materials

	Distance	100 µm			200 µm			300 µm		
	Depth	20 µm	40 µm	60 µm	20 µm	40 µm	60 µm	20 µm	40 µm	60 µm
Enamel	Ketac Cem	174.1 (54.4)	288.5 (64.1)	282.3 (92.3)	256.3 (108.0)	313.9 (102.6)	320.3 (47.0)	273.6 (119.1)	242.0 (78.0)	266.3 (90.1)
	Ionoseal	250.4 (57.0)	218.5 (63.7)	190.9 (47.9)	230.9 (42.0)	192.3 (37.6)	182.4 (38.2)	181.6 (38.6)	157.1 (27.3)	145.2 (31.1)
	Ionofast	202.1 (65.4)	152.6 (38.5)	148.5 (41.7)	188.7 (66.5)	174.7 (57.1)	154.5 (55.5)	185.1 (69.1)	168.6 (57.1)	138.2 (45.1)
	Filtek Z250	127.7 (27.1)	148.7 (66.0)	149.5 (57.8)	151.8 (40.3)	155.8 (50.5)	156.4 (70.1)	157.8 (44.2)	182.3 (50.0)	157.3 (42.7)
Dentin	Ketac Cem	52.4 (17.4)	47.3 (6.92)	48.0 (8.81)	44.28 (13.4)	45.4 (8.3)	54.3 (18.8)	42.4 (11.0)	44.7 (12.6)	48.6 (12.6)
	Ionoseal	57.8 (14.4)	70.9 (12.1)	61.0 (15.4)	51.3 (14.4)	63.1 (14.4)	60.9 (16.5)	52.2 (19.8)	51.5 (13.5)	52.4 (10.6)
	Ionofast	55.6 (18.4)	47.1 (16.3)	54.0 (19.3)	52.0 (13.8)	47.9 (13.8)	45.2 (9.8)	48.1 (15.3)	46.7 (15.3)	49.0 (13.3)
	Filtek Z250	38.7 (14.0)	33.8 (9.0)	35.04 (11.0)	35.4 (8.9)	37.2 (12.6)	38.2 (12.7)	38.2 (11.5)	41.2 (11.8)	37.3 (12.1)

Legend: Three-way repeated measures ANOVA demonstrated that there was not statistically significant triple interaction for restorative material, distance, and depth (P = 0.271).
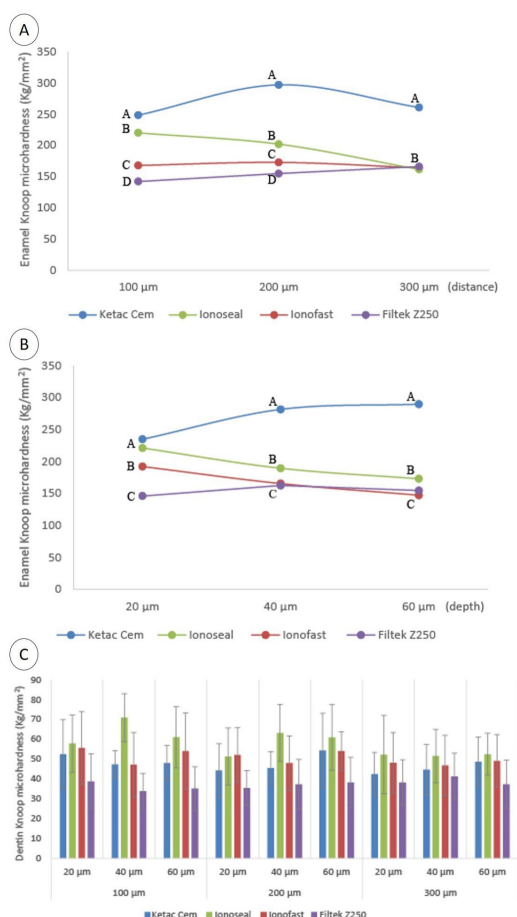
Figure 2 - Knoop microhardness of enamel and dentin considering the factors separately. (A) Knoop microhardness values at different distances from the enamel adjacent to restorative materials; (B) Knoop microhardness values at different depths from the enamel adjacent to restorative materials; (C) Knoop microhardness values at different distances and depths of dentin adjacent to restorative materials. Legend: Materials identified by different letters differ significantly from each other, considering each factor separately (distance or depth).

with significantly higher values of microhardness compared to the other materials (Ionofast and Filtek Z250). At greater depths (40 and 60 μm), the microhardness obtained with Ketac Cem significantly surpassed that associated with Ionoseal. This, however, remained providing significantly higher microhardness than the Ionofast and Filtek Z250, which ceased to differ significantly.

Considering the distances and depths of enamel, after pH-cycling model the microhardness in the enamel adjacent to the Ketac Cem showed a behavior according to a quadratic polynomial function (parabola, Table III), providing greater microhardness at 200 μm distance (Figure 2A and Table III), and at 40 μm and 60 μm deep (Figure 2B and Table III). As for the other materials, the behavior curves over distances and depths were linear (Table III), indicating a reduction in microhardness values over more distant and deeper locations for Ionoseal. The same event was observed for Ionofast with increasing depth. The composite resin (Filtek Z250) presented a more constant profile and microhardness values over distances and depths (Figure 2A, Figure 2B and Table III).

For dentin, the three-way repeated measures ANOVA did not identify a statistically significant triple interaction between the restorative material, distance, and depth factors ($P = 0.738$). None of the double interactions was also significant: restorative material vs. distance ($P = 0.206$), restorative material vs. depth ($P = 0.215$), and

Table III - Functions that govern the Knoop microhardness of each restorative material over the enamel distances and depths adjacent to base and restorative materials

Material	Distance	Depth
Ketac Cem	$MD = -42.367d^2 + 175.633d + 115.033$ $r^2 = 1.000$	$MP = -19.317p^2 + 104.750p + 149.233$ $r^2 = 1.000$
Ionoseal	$MD = -29.312d + 252.993$ $r^2 = 0.953$	$MP = -24.062p + 242.493$ $r^2 = 0.968$
Ionofast	$MD = -6.783d^2 + 25.267d + 149.227$ $r^2 = 1.000$	$MP = -22.457p + 213.018$ $r^2 = 0.988$
Filtek Z250	$MD = 11.922d + 130.299$ $r^2 = 0.999$	$MP = -12.167p^2 + 53.000p + 104.920$ $r^2 = 1.000$

distance vs. depth ($P = 0.781$). Nevertheless, the restorative materials differed statistically from each other ($P < 0.001$) considering the individualized factor (material), and with the Ionoseal presented significantly higher values of dentin microhardness, regardless of the distance and depth (Table II and Figure 2C). The materials Ionofast and Ketac Cem did not differ significantly in relation to the microhardness provided to dentin in the face of pH-cycling, and the use of both resulted in significantly higher microhardness than that found for Filtek Z250. Finally, the statistical analysis revealed that the distance ($P = 0.067$) and the depth ($P = 0.771$) did not significantly affect the values of dentin microhardness adjacent to restorative materials.

DISCUSSION

Among the four materials studied, Ionoseal, Ionofast and Ketac Cem have, in common, due to their ionomeric characteristics, the clinical indication for "*sandwich technique*", "*open-sandwich technique*", *or* provisory restorations [18,21,25]. Specifically, modified-GICs (Ionoseal and Ionofast) are materials with composition including ionomer and composite resin products, allow a quicker, easier, and more precise application inside the cavity by being inserted with the aid of a syringe, and the setting of these materials occurs after photoactivation. The conventional glass ionomer cement (Ketac Cem) must be handled in the amount of powder and liquid recommended by the manufacturer and inserted into the cavity with the aid of manual applicators or applicator syringes [18,25]. The microhybrid composite resin (Filtek Z250) was the only material studied that is only restorative, therefore, it was the control group with an unexpected remineralizing effect. At any distance and depth, the lowest microhardness values were obtained for composite resin. In fact, the composite resin does not release

fluoride and therefore has no effect in inhibiting demineralization.

The results of enamel and dentin microhardness found in this study revealed better performance of conventional GIC (Ketac Cem) in enamel, and a more discreet effect in dentin for PMCR (Ionoseal), therefore, the null hypothesis was refuted. The increase or decrease of microhardness in *in vitro* investigations is an indirect measure of lesser or greater loss of minerals by a demineralization event, since there is a significant correlation between Knoop hardness and the percentage of mineral content [26]. In this sense, the maintenance of microhardness around restorations is associated with the amount of fluoride or others bioactive/remineralizing actives released by the material and is explained by several mechanisms, including the reduction of demineralization [14,15,26]. The action mechanism of fluoride in/on dental structures is suggested by the presence of fluorapatite crystals and calcium fluoride bioavailability during re- and demineralizing events.

Fluoride-releasing materials should be considered to keep the ion constantly in the mouth. GICs, in addition to releasing fluoride for a long time, can also be recharged with ions from other sources, such as fluoride toothpastes. In addition, these materials offer the fluoride most used in the oral cavity, because the ion is kept constantly in the right place (next to the biofilm), at the right time (whenever sugar is ingested) and in sufficient concentration (low levels) to increase remineralization [14,15].

For example, considering "*open-sandwich*" techniques, the operator could select a substitute for dentin (GIC, RMGIC, PMCR) and an enamel analog (composite resin). Under occlusal contact, the glass ionomer undergoes excessive wear in the long run. Therefore, in association with the glass ionomer, the *open-sandwich* technique recommends the use of composite resin to restore the occlusal surface, thus achieving

the necessary aesthetic benefit and mechanical resistance [8,15,18]. The composite resin, when applied on the PMCR, complements the chemical bond it obtains with the tooth structure by micromechanical bonding. This double adhesion mechanism is the main determinant of material retention and marginal sealing capacity. In this case, greater bonding and sealing resistances will be achieved with PMCR than with conventional GIC [18].

For dentin, it was found that the materials had statistically different values, and PMCR (Ionoseal) presented the highest microhardness values, regardless of distance and depth. Nevertheless, the PMCR (Ionoseal) and GICs (Ketac Cem) did not differ in relation to the microhardness provided to dentin. The differences of microhardness results in dentin were not as expressive as those in enamel, possibly due to the ultramorphological and composition differences of these dental hard tissues. PMCR (Ionoseal) differed from RMGIC (Ionofast), this finding can probably be related to the percentage of the ionomeric material of fluoride release, believing that the amount of ion release is different in the two products. Fluoride release varies according to the source, size and concentration of particles containing fluoride, as well as the composition, solubility, and permeability of the resin matrix [26]. According to MSDS - Safety Data Sheet, Ionoseal has 50 to 60% ionomer, however the same information was not found for the Ionofast.

Ionoseal (PMCR) is composed of nanoparticles that provide an elasticity module similar to that of dentin, has a small contraction after photoactivation and a characteristic of adequate surface hardness. Moreover, the fluidity/viscosity has the advantage of better adaptation to the cavity walls, which would allow a better degree of marginal sealing. In comparison, Ionoseal contains monomers or resin products, may have favored the strengthening and sealing of the dentin surface. One reason is that crosslinked polymers in polymers and composites (typically Bis-GMA, DUDMA and HEDMA copolymers) generally have greater strength and toughness than the gel network formed by the acid-base reaction in GIC. In addition, the fluoride in its composition could provide maintenance of microhardness values after the acid challenge, whereas in comparison with other materials (GIC and RMGIC), the highest values of compressive strength after setting were obtained by PMCR (Ionoseal) in a previous study [27].

The advantages of GIC are the potential of fluoride release and good adhesion to the dental structure, in addition to the low cost, easy handling and insertion, thermal insulation, biocompatible, antimicrobial, low solubility and reduction of the acid environment and potentially capable of remineralizing [21,25]. However, limitations are related to their low cohesive and compressive resistance to wear and traction, low fracture toughness, limited durability, high initial solubility and risk of loss or incorporation of water that can result in dimensional changes. In addition to the loss of mechanical properties and the formation of cracks, a high risk of infiltration and fracture in composite cavities, sensitivity to moisture during the chemical reaction, this may result in loss of translucency and limited durability.

Despite the great potential for fluoride release, GIC, in dentin, is unable to produce an effective seal. It has great sensitivity to moisture and dehydration after setting, which allows its surface to show cracks [18]. Nowadays, conventional GIC is practically no longer suitable for permanent restorations, apart from prophylactic sealing of fissures or restoration in pediatric dentistry [8]. The best sealing of the PMCR compared to RMGIC could be due to the formation of more stable resin tags inside the dentinal tubules together with the ion exchange process present at the interface between the dentin and the PMCR [18]. Considering the results of the present study, although pH-cycling model is an established *in vitro* method to simulate demineralizing events, new studies, especially *in vivo* or *in situ*, are encouraged in order to better understand the behavior of fluoride-releasing materials.

CONCLUSION

The conventional glass ionomer cement provided a better effect in maintaining enamel microhardness around restorations. In dentin, the polyacid-modified composite resin obtained better performance than resin-modified glass ionomer cement.

Author's Contributions

RCF: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing, Visualization. WFVJ: Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing, Visualization. RTB: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Visualization. CPT: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Visualization. FLBA: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Visualization. FMGF: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing, Visualization, Supervision, Project Administration.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of: Declaration of Helsinki. The approval code for this study is: CAAE: 14127019000005374.

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