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Susceptibility of restorations and adjacent enamel/dentine to erosion under different salivary flow conditions

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Objectives: The aim of this study was to investigate the effect of erosion on direct tooth-coloured restorations and adjacent enamel/dentine under low and normal simulated salivary flow rates.
Methods: Bovine enamel and dentine specimens were prepared ($n = 16$) and restored with the following materials: resin composite (FiltekZ250), resin-modified glass ionomer cement (Fuji II LC), high-viscosity glass ionomer cement (Fuji IX), and conventional glass ionomer cement (Fuji II). They were submitted to *in vitro* erosion–remineralisation cycling simulating normal (0.5 ml/min) and low (0.05 ml/min) salivary flow rates, for 5 days. The restorative material, enamel and dentine substrates were assessed with optical profilometry for surface loss. Mixed-model ANOVAs were used for statistical comparisons (alpha = 0.05).
Results: Low-salivary flow significantly increased surface loss for all tested substrates ($p < 0.05$), except FiltekZ250. Surface loss (mean ± SD, in micrometres) under low-salivary flow was significantly higher in enamel (19.75 ± 4.27) and dentine (23.08 ± 3.48) adjacent to FiltekZ250 compared to Fuji II LC (16.33 ± 2.30 and 20.47 ± 2.58, respectively) and Fuji IX (15.79 ± 2.41 and 20.63 ± 2.34, respectively). Restoration surface degradation was significantly lower for Fuji II LC (2.17 ± 0.73) than for both Fuji II (13.03 ± 6.79), and Fuji IX (16.74 ± 7.72) under low-salivary flow condition; whereas FiltekZ250 exhibited no meaningful surface loss (−0.35 ± 0.19).
Conclusion: Limited to these *in vitro* conditions, low-salivary flow promoted higher erosive conditions for teeth and restorations. Some fluoride-containing restorative materials may reduce erosive wear on adjacent enamel and dentine. FiltekZ250 resisted erosive surface loss. Fuji II LC showed both reduced acid degradation and protection of adjacent dental surfaces to erosion.
Clinical significance: Patients at risk for erosion and in need of restorations may benefit from fluoride-containing restorative materials that resist erosive degradation. The data of this study suggest that resin-modified glass ionomer may be a suitable restoration for patients at higher risk of erosion with low exposure to fluoride.

1. Introduction

Dental erosion is a multifactorial condition that causes irreversible loss of dental hard tissues without bacterial involvement [1]. Its prevalence has increased significantly due to frequent exposure of teeth to acids, mostly through the consumption of acidic beverages [2]. Efforts have been made to identify the etiological factors involved in the erosion process to aid in the development of reliable preventive and restorative treatments.

Saliva is considered an important factor modulating dental erosion. It can clear and neutralise erosive acids, form acquired dental pellicle and remineralise eroded dental hard tissues [3]. These protective mechanisms can be potentially reduced in patients with low salivary flow rate. Studies have shown that erosion is associated with low salivary flow rate and/or low buffering capacity [4,5]. According to Jarvinen et al. [6], patients with unstimulated salivary flow rate of 0.1 ml/min or less were at

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five-times greater risk of erosion than those with normal flow rates.

Management of dental erosion includes preventive and restorative measures, which are determined by the risk status and complexity of the case. With the recent advancement in adhesive dentistry, erosive tooth loss can be restored conservatively by direct bonded materials, including resin composite, conventional glass ionomer cements (GICs) and their hybrids. However, restorations can also be affected by erosive acids, potentially decreasing their clinical performance and longevity [7,8]. Resin composite has shown the best resistance to acid degradation, but do not release fluoride [9,10].

GICs possess some advantages over resin composites such as good adhesion to enamel and dentine, coefficient of thermal expansion similar to tooth structure and long-term fluoride release. Evidence has shown that the high-viscosity GIC presents favourable outcomes considering anatomical form in patients with radiation-induced caries where the saliva is critically low [11]; however, GICs generally exhibit inferior mechanical properties compared to resin-modified glass ionomer (RMGI) cement and resin composite especially under erosive challenge [12].

Although some studies have shown that fluoride releasing restorations play an important role reducing dental erosion progression [9–13], no consensus has been established [14–16]. Furthermore, there is evidence suggesting that fluoride release and improved mechanical properties are determinant factors for restoration longevity under hyposalivatory conditions [17–19]; nonetheless, there is not enough information regarding the recommendation of restorative materials for hyposalivatory patients suffering from dental erosion.

We hypothesize that restorations that release fluoride and present improved mechanical properties (RMGI and high-viscosity GIC) are more resistant to acid degradation than conventional GIC and provide better protection to surrounding dental substrates compared to resin composite under highly erosive conditions such as those observed in hyposalivatory patients. To date, this has not been studied under standardised *in vitro* conditions.

This *in vitro* study aimed to evaluate the effect of erosion on direct tooth coloured restorations and adjacent enamel and dentine, under low and normal salivary flow rates, and to evaluate the impact of restorative materials on enamel and dentine erosive wear.

2. Materials and methods

2.1. Study design

Two experimental factors were investigated in this *in vitro* study: restorative dental materials at four levels (Table 1), and simulated salivary flow rate at two levels (low and normal), in an erosion–remineralisation cycling model [20]. These factors were tested independently on the surfaces of bovine enamel and root dentine, as well as of restorative materials. Specimens were prepared ($n = 16$/group), restored and submitted to the testing protocol for 5 days. This study was conducted according to the complete block design with 4 repetitions per block. Surface loss of the restorative materials and surrounding enamel and dentine surfaces was the study outcome measure, expressed in μm. The experimental sequence is schematically illustrated in Fig. 1.

2.2. Specimen preparation

Two hundred and thirty enamel and dentine slabs obtained from bovine incisors were cut (4 mm width × 4 mm length × 2 mm thickness) using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) and ground using 1200-grit paper (MD-Fuga, Struers Inc., Cleveland, Ohio, USA). One enamel and one dentine specimen were positioned 0.5–0.8 mm apart from each other in the centre of a square rubber mould (10 mm × 10 mm × 8 mm) then embedded in acrylic resin (Varidur, Buehler) to form a resin block. The resin blocks were sequentially ground and polished with 500-, 1200-, 2400- and 4000-grit papers (MD-Fuga, Struers Inc.) on an automated grinding/polishing machine at 300 rpm (Rotoforce-4, Struers Inc.) under irrigation with deionized (DI) water. Following the polishing procedure, the specimens were placed under running DI water for 3 min. The specimens were inspected with stereomicroscopy at 20× to choose 128 specimens without visible cracks or other flaws. They were randomised into the 8 experimental groups according to the restorative materials used (Table 1) with low or normal salivary flow rate ($n = 16$/group) and maintained in 100% relative humidity condition.

2.3. Restorative materials application

For each specimen, a box-shaped cavity (1.2 × 4 × 2 mm) was manually prepared between the enamel and dentine slabs using a diamond fissure bur (No. 835KR.31.008, Brasseler USA, Savannah, GA) in a high-speed handpiece with air-water coolant. The cavity was filled with its respective restorative material according to manufacturer instructions then covered with a polyester strip. A glass slide was placed over the strip and a static load of 0.53 kg was applied using a heavy glass slab to allow excess material to extrude over the top of the cavity margins and to ensure that the material was flush with the surface of enamel and dentine. The glass slab was then removed and materials requiring light polymerisation were cured through the polyester strip and glass slide using a Demetron Optilux VCL 401 (Kerr, USA) light curing unit, with minimum irradiance of 400 mW/cm^2 (Cure Rite; Dentsply, USA). The specimens were kept in 100% relative humidity at 37 °C for one week before testing to allow post-irradiation hardening of composite restorations and stabilisation of the setting reaction of GIC restorations [7]. They were finished and polished using the same grinding and polishing procedure described in the specimen preparation section. Adhesive unplasticised polyvinyl chloride tape (UPVC) was placed on two sides of the specimens, leaving an

Table 1
Study groups according to restorative dental materials.

Material /group	Manufacturer	Classification	Shade	Lot No.
Filtek Z250	3M-ESPE, St. Paul, MN, USA	Microhybrid resin composite	A2	N546786
Fuji II	GC Corporation, 76-1Hasunuma-Cho, Itabashi-Ku, Tokyo, Japan	Conventional GIC	A2	1305011
Fuji IX	GC Corporation, 76-1Hasunuma-Cho, Itabashi-Ku, Tokyo, Japan	High-viscosity GIC	A2	1311051
Fuji II LC	GC Corporation, 76-1Hasunuma-Cho, Itabashi-Ku, Tokyo, Japan	RMGI	A2	1311081

GIC, glass ionomer cement; RMGI, resin-modified glass ionomer cement.