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Protective effects of resin sealant and flowable composite coatings against erosive and abrasive wear of dental hard tissues

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ABSTRACT

Objectives: To test the effectiveness of sealant and flowable composite coating on eroded enamel, dentin and cementum under erosive/abrasive challenges in vitro.
Methods: A total of 108 tissue sections (36 each for enamel, dentin and cementum) from third molars were assigned to three groups: Seal & Protect sealant (S&P), Tetric EvoFlow composite (TEF) and control. Erosive/abrasive lesions were created on each specimen by citric acid and brushing with toothpaste. S&P and TEF were applied to the lesions and subjected to erosive/abrasive cycling included 24 cycles of immersion in citric acid (pH 3.6) for 60 min, followed by remineralization for 120 min and brushing with toothpastes for 600 strokes at 150 g. Erosive wear of materials or dental tissues were measured with 3D scanning microscopy and data were analyzed using ANOVA.
Results: Treatments with S&P and TEF created a protective material coating of 42.7 ± 17.8 μm and 150.8 ± 9.9 μm in thickness, respectively. After 24 cycles of erosive/abrasive challenges, tissue losses were -346.9 ± 37.3 μm for enamel, -166.5 ± 26.3 μm for dentin and -164.7 ± 18.2 μm for cementum in untreated controls, as compared to material losses of -24.4 ± 3.3 μm for S&P, and -10.8 ± 4.4 μm for TEF, respectively. Both S&P and TEF were effective in protecting enamel, dentin and cementum against erosive tooth wear ($p < 0.01$). S&P exhibited faster wear than TEF ($p < 0.01$) and showed spotted peeling in a third of the specimens. TEF remained intact on all three types of dental tissues at the end of the 24 cycles of erosive/abrasive challenges.
Conclusions: A thin coating of flowable composite resin 150 μm in thickness may provide long-term protection against erosive/abrasive tooth wear. Resin sealant may provide adequate protection for dental hard tissues in short-term and may require repeated applications if long-term protection is desired.

1. Introduction

Erosive tooth wear commonly presents as shallow concavities on smooth surfaces occurring coronal from the cemento-enamel junction (CEJ) [1]. Wedge-shaped lesions that require the Class V restorations may develop with progression of the cervical wear. Such lesion was found to begin on cementum apical to the CEJ, subsequently involve underlying dentin, and eventually undermine enamel following the loss of cementum and dentinal tissues at the CEJ [2]. As erosive tooth wear compromises integrity of dental hard tissues and affects the quality of life in populations of all ages [3], its effective prevention is of paramount importance for dental professionals.

A protective coating that isolates dental hard tissues from acid contact and resists toothbrush abrasion may provide protection against erosive and abrasive challenges. In experiments in vitro, resin-based materials were able to prevent enamel erosion by hydrochloric and citric acid under long-term exposures [4], and provided protection against erosive and abrasive wear of dental enamel for two years under tooth brushing abrasive challenges [5].

Despite cervical wear is one of the most common form of erosive tooth wear and may lead to the formation of wedge-shaped cervical lesions, few studies have looked into the potential of resin-based materials for prevention of cervical erosive and abrasive wear. It is well recognized that non-carious cervical wear usually begins at CEJ, where cementum, enamel and dentinal tissues meet and form a unique tissue juncture that is vulnerable to mechanical, chemical and bacterial insults when exposed to the oral environment [6,7]. Application of resin-based materials to exposed CEJ

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may isolate this area from extrinsic mechanical and chemical insults and prevent the progression of cervical wear. Though resin-based materials were shown to be effective against erosive wear of dental enamel in a recent study [5], it is not known if similar protective effects could be achieved on dentin and cementum as these tissues differ greatly from enamel in structure and properties.

The resin-based materials used in previous laboratory and clinical studies were limited to the lowly filled bonding agents or sealants [4,5,8–11]. The protective effects of these materials were often described as temporary in nature, presumably due to their lack of resistance to erosive and abrasive wear [9,12]. The highly filled composite resin materials may have the potential to improve the long-term outcomes as they have demonstrated high durability under erosive and abrasive attacks [13].

The aim of this study was therefore to investigate the protective effects of different resin-based coating materials against erosive and abrasive wear of enamel, dentin and cemtentum in vitro. We tested the hypothesis that a resin composite coating is superior to a sealant coating in protecting dental hard tissues against erosive and abrasive wear.

2. Materials and methods

2.1. Sample preparations

Enamel, dentin and cementum sections, 36 pieces each, were cut from the third molar with a water-cooled low speed diamond saw (MTI Corporation, Richmond, CA). A flat surface area approximately $3 \times 3\,mm^2$ was created on each specimen using 600, 1200, 2400 and 4000 grit (Extec Corporation, Enfield, CT) carbide paper on a rotating polishing machine (Unipol-810, MTI Corporation, Richmond, CA) under constant water irrigation.

2.2. Creation of erosive and abrasive lesions on enamel surfaces

All 108 specimen discs were partly covered with an adhesive tape to leave a $2\,mm \times 2\,mm$ band of exposed tissue surfaces. Each sample was then placed in individual containers with 15 ml of 0.034 M citric acid (Sigma–Aldrich Co., St. Louis, MO) at pH 3.6 for 30 min at 35 °C with gentle shaking (100 rpm) on a rocking incubator to simulate sipping a drink. The specimens were then rinsed in distilled water for 30 s, followed by immersion of each sample in 20 ml of artificial saliva for 60 min. The composition of the artificial saliva (pH 7.0) was adopted from Oliveira et al. [14] and contained the following chemicals in one liter of distilled water: 0.33 g KH_2PO_4; 0.34 g Na_2HPO_4; 1.27 g KCl; 0.16 g NaSCN; 0.58 g NaCl; 0.17 g $CaCl_2$; 0.16 g NH_4Cl; 0.2 g urea; 0.03 g glucose; 0.002 g ascorbic acid. Artificial saliva was prepared freshly every day. Exposed surface of each specimen was then brushed with a toothbrushing machine (Proto-tech, Portland, OR) for 300 strokes at a frequency of 120 strokes/min under 150 g pressure using the ADA standard toothbrush with a slurry of toothpaste (Crest® Cavity Protection, Procter & Gamble, Cincinnati, OH) and artificial saliva at 1:3 ratio by weight.

After the erosive and abrasive challenging cycles, adhesive tapes were removed and the surface profiles of the enamel, dentin and cementum were evaluated with a focus-variation 3D scanning microscopy (InfiniteFocus® G4, Alicona Imaging, Grambach/Graz, Austria) to capture the 3D topography of the eroded tissue surfaces [15,16]. Cementum specimens were inspected again at x1,000 magnification to ensure that no dentin tubules were exposed and the erosion remained within the limit of cementum tissue. The images of the erosive and abrasive lesions were taken at magnifications of approximately 200 with vertical resolutions of 0.1 μm. The depth of tissue wear was measured in μm at the maximum depth of the profile in 5 locations and the average of the 5 measurements was used to represent the erosive tissue wear.

2.3. Treatment of the erosive and abrasive lesions with resin-based materials

The enamel, dentin and cementum specimens with erosive and abrasive lesions were randomly assigned to three treatment groups, with 12 specimens in each group. After randomization, the adhesive tapes were replaced on the enamel surfaces to leave only the lesions exposed. The exposed enamel, dentin and cementum lesions were treated as follows: Group 1. No treatment, as negative control. Group 2. Coating of enamel, dentin and cementum lesions with a resin-based sealant (S&P). The lesion area was rinsed with water spray and air-dried, and the resin-based sealant Seal & Protect (Dentsply DeTrey GmbH, Konstanz, Germany) was applied for 20 sec. After air-drying for 5 s to remove the solvent, the sealant was light-cured for 10 s. The sealant was reapplied for 10 s, air-dried and light-cured again for 10 s. Group 3. Coating of enamel, dentin and cementum lesions with a flowable composite (TEF). The lesions were etched with 32% phosphoric acid gel (UNI-ETCH, BISCO Inc., Schaumburg, IL) for 15 s. After rinsing with water for 15 s and gently air-drying, a resin adhesive (OptiBond Solo Plus, Kerr Corp., Orange, CA) was applied for 15 s using a light brushing motion, and air-thinned for 3 s to avoid pooling before light curing for 5 s. A flowable composite resin, Tetric EvoFlow (Ivoclar Vivadent Inc, Amherst, NY), was applied and light cured for 10 s, and polished with Sof-Lex (3 M ESPE, St. Paul, MN) polishing discs in sequences of 4 from coarse to superfine following the manufacturer's instruction.

2.4. Erosive and abrasive challenges of treated lesions

After treatments with resin-based materials, enamel, dentin and cementum specimens in the 3 study groups were once again subjected to erosive challenges by citric acid and abrasive challenges by toothbrushing. Each erosive and abrasive challenging cycle included immersion of the specimens in citric acid (pH 3.6) for 60 min, in artificial saliva for 120 min and brushing for 600 strokes with the toothpaste slurry under 150 g of pressure at 35 °C. The specimens were placed in artificial saliva overnight between treatment cycles.

A total of 24 cycles of erosive and abrasive challenges were completed and the erosive wear of the treated areas were assessed with the 3D scanning microscopy at the end of 6, 12, 18 and 24 cycles of erosive and abrasive challenges. The depth of tissue or material wear was measured in μm at the maximum depth of the profile in 5 locations and the average of the 5 measurements was used to represent the erosive wear of the lesions in the control group or the material loss of the resin coating remained on the lesion surfaces in the study groups.

2.5. Statistical analyses

Two-factor analysis of variance (ANOVA) and the post hoc Fisher's least significant difference tests were used to compare tissue and material loss among the experimental groups. The two-factor repeated measures ANOVA and post hoc paired-*t* tests were used to compare tissue and material wear with time within the same group. All statistic analyses were conducted using the StatView 5.01 software (SAS Institute, Cary, NC). Bonferroni correction was applied to account for the effect of multiple comparisons.