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Sodium fluoride effect on erosion–abrasion under hyposalivatory simulating conditions

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ABSTRACT

Objectives: To investigate the effect of fluoride (0, 275 and 1250 ppm F; NaF) in combination with normal and low salivary flow rates on enamel surface loss and fluoride uptake using an erosion–remineralization–abrasion cycling model.

Design: Enamel specimens were randomly assigned to 6 experimental groups ($n = 8$). Specimens were individually placed in custom made devices, creating a sealed chamber on the enamel surface, connected to a peristaltic pump. Citric acid was injected into the chamber for 2 min followed by artificial saliva at 0.5 (normal flow) or 0.05 (low flow) ml/min, for 60 min. This cycle was repeated 4×/day, for 5 days. Toothbrushing with abrasive suspensions containing fluoride was performed for 2 min (15 s of actual brushing) 2×/day. Surface loss was measured by optical profilometry. KOH-soluble fluoride and enamel fluoride uptake were determined after the cycling phase. Data were analysed by two-way ANOVA.

Results: No significant interactions between fluoride concentration and salivary flow were observed for any tested variable. Low caused more surface loss than normal flow rate ($p < 0.01$). At both flow rates, surface loss for 0 was higher than for 275, which did not differ from 1250 ppm F. KOH-soluble and structurally-bound enamel fluoride uptake were significantly different between fluoride concentrations with 1250 > 275 > 0 ppm F ($p < 0.01$).

Conclusions: Sodium fluoride reduced enamel erosion/abrasion, although no additional protection was provided by the higher concentration. Higher erosion progression was observed in low salivary flow rates. Fluoride was not able to compensate for the differences in surface loss between flow rates.

1. Introduction

Saliva has an important protective effect against dental erosion due its ability to clear, dilute and buffer erosive solutions. Besides, it contains calcium, phosphate and fluoride which can potentially reduce demineralization and enhance remineralization of the surface-softened layer of the lesion.[1,2] The salivary flow rate has been considered the most important single parameter to determine the protective effect of saliva, since practically all other salivary parameters depend on it.[3] In healthy individuals, saliva covers the dental tissues at all times[4] and the average unstimulated salivary flow rate is 0.5 ml/min.[5] Flow rates below 0.1 ml/min are indicative of

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hyposalivation,[2] which has been associated with the presence of dental erosion.[6,7] Preventive measures for this population include the regular use of fluoride and saliva substitutes.

Dentifrices have been adopted worldwide as the main vehicle for fluoride delivery, with sodium fluoride being the most used compound.[8,9] Its concentration typically ranges between 1100 and 1450 ppm F, with clinically proven anti-caries efficacy.[10] However, at these concentrations, fluoride's protection against dental erosion–abrasion is thought to be limited.[11,12] It can be suggested that toothpastes with a higher concentration of fluoride (5000 ppm F) can provide more effective protection, but controversial outcomes have been reported. Ren et al.[13] found less enamel erosion for 5000 ppm F in comparison to a sodium fluoride dentifrice with 1450 ppm F. On the other hand, Rios et al.[14] did not observe any anti-erosive effects with the 5000 ppm F sodium fluoride dentifrice. In view of these contrasting results, further investigation is necessary to clarify the role of highly concentrated fluoride dentifrices in dental erosion prevention, especially in high-risk hyposalivatory patients.

Only few investigations have tested the clinical effectiveness of preventive and therapeutic measures against dental erosion in the hyposalivatory population,[15,16] showing that there is a need for more agents and protocols to be developed. Recently, there has been increasing attention for the development of novel technologies with potential impact on dental erosion prevention. Therefore, it is necessary to initially test them against existing preventive agents for their anti-erosion potential in a fast, well-controlled and relevant manner. In vitro models capable of simulating some of the low salivary flow effects in erosion, especially acid clearance and dilution are necessary. Promising agents identified in vitro could then be later tested in more clinically relevant conditions.

In this in vitro study, we hypothesized that higher fluoride concentration would show improved protection against dental erosion–abrasion; and that this protection would be more evident under low salivary flow conditions. The objectives of this study were: (1) to evaluate the protection of different sodium fluoride concentrations on enamel erosion–abrasion, under low and normal salivary flow rates; (2) to propose and test an in vitro model for the study of dental erosion, simulating the effects of hyposalivation.

2. Materials and methods

2.1. Study design

This study tested two experimental factors: abrasive suspensions with three fluoride contents (0, simulating a non-fluoridated dentifrice; 275 ppm F, simulating a 1100 ppm F dentifrice; and 1250 ppm F, simulating a 5000 ppm F dentifrice) and salivary flow (at 2 levels: normal and low) in an erosion–remineralization–abrasion cycling model using bovine enamel specimens ($n = 8$). The response variables were enamel surface loss (in μm), KOH-soluble and structurally-bound enamel fluoride uptake (μg/cm^2) measured at the end of the cycling phase. All the analyses were performed in random sequence and in blind conditions.

2.2. Specimen preparation

Enamel slabs (4 mm width × 4 mm length × 2 mm thickness) were cut from bovine incisors using a microtome (Isomet, Buehler, Lake Bluff, IL, USA). The specimens were embedded in acrylic resin (Varidur, Buehler) and the resulting blocks (10 mm × 10 mm × 8 mm) were ground flat and polished with water-cooled abrasive discs (500-, 1200-, 2400- and 4000-grit Al_2O_3 papers; MD-Fuga, Struers Inc., Cleveland, OH, USA) and polishing cloth with diamond suspension (1 μm; Struers Inc.). After the polishing procedures, they were sonicated in 2% detergent solution (2% micro-90 liquid soap, International Product Corporation, Burlington, NJ, USA) and selected. Specimens with any cracks or structure defects were discarded. Adhesive unplasticized polyvinyl chloride (UPVC) tapes were placed on the polished surface of each specimen, leaving an area of 4 mm × 1 mm exposed to subsequent testing. Specimens were then randomly assigned to six experimental groups ($n = 8$ per group).

2.3. Erosive/abrasive challenges

The daily cycling sequence is shown in Table 1. The erosive challenge was performed with a 0.3% citric acid solution (pH = 2.6, natural pH). A multichannel peristaltic pump (Masterflex LS, Cole Palmer, IL, USA) was used to simulate the acid flow rate. The specimens were individually placed in custom made acrylic devices (4 specimens/device), having their polished enamel surfaces facing a closed chamber of 41.3 μl capacity. Each chamber was connected to one inlet and one outlet fluid tubes, with a mechanism of fluid flow similar to the one described by Wiegand et al.[17] The inlet tube was connected to the pump through a two-way tubing system, which included a second free-end tube to allow the elimination of the air bubbles during the experimental procedures. Before the first acid challenge of the day, deionized water was rinsed into the chambers to remove the air through the tube with the free end. For this procedure, the tube connected to the pump was closed with tubing pinch clamps. Once the water had filled the chamber, the free-end tube was closed and the tube connected to the pump was opened. Citric acid was then injected into the chambers at a 0.6 ml/min rate for 2 min, at room temperature.

After the erosive challenge, the device was connected to the other pump for remineralization. During this procedure,

Table 1 – Daily cycling sequence.

Steps	Procedures	Treatments
1	Erosive challenge	Citric acid (2 min)
	Remineralization	Artificial saliva (30 min)
	Brushing	45 strokes (2 min suspension exposure)
	Remineralization	Artificial saliva (30 min)
2	Erosive challenge	Citric acid (2 min)
	Remineralization	Artificial saliva (60 min)
	Repeat Step 2	
	Repeat Step 1	
	Overnight storage in humid environment at 4 °C	

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