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Anti-erosive properties of solutions containing fluoride and different film-forming agents

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ABSTRACT

Objectives: To evaluate the anti-erosive potential of solutions containing sodium fluoride (NaF, 225 ppm F) and different film-forming agents.

Methods: In Phase 1, hydroxyapatite crystals were pre-treated with solutions containing NaF (F), linear sodium polyphosphate (LPP), sodium pyrophosphate tetrabasic (PP), sodium tripolyphosphate (STP), sodium caseinate (SC), bovine serum albumin (BSA), stannous chloride (Sn) and some combinations thereof. Deionized water was the control (C). The pH-stat method was used to evaluate hydroxyapatite dissolution. In Phase 2, the most effective solutions were tested in two independent experiments. Both consisted of an erosion–remineralization cycling model using enamel and dentine specimens with three solution treatments per day. In Phase 2a, the challenge was performed with 0.3% citric acid (pH = 3.8). In Phase 2b, 1% citric acid (pH = 2.4) was used. Hard tissue surface loss was determined profilometrically. Data were analyzed with two-way ANOVA and Tukey tests.

Results: In Phase 1, F, LPP, Sn and some of their combinations caused the greatest reduction in hydroxyapatite dissolution. In Phase 2a, C showed the highest enamel loss, followed by LPP. There were no differences between all other groups. In Phase 2b: (F + LPP + Sn) < (F + LPP) = (F + Sn) < (F) = (LPP + Sn) < (LPP) < (Sn) < C. For dentine, in both experiments, only the fluoride-containing groups showed lower surface loss than C, except for LPP + Sn in 2a.

Conclusions: F, Sn, LPP reduced enamel erosion, this effect was enhanced by their combination under highly erosive conditions. For dentine, the F-containing groups showed similar protective effect.

Clinical significance: The addition of LPP and/or Sn can improve the fluoride solution protection against erosion of enamel but not of dentine.

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1.   Introduction

Q4 Epidemiological studies have demonstrated that erosive tooth wear (ETW) is a common dental condition worldwide.[1] During the initial stages, the signs and symptoms of ETW are seldom perceived by the patients. In advanced cases, however, pain as result of dentine exposure, as well as loss of tooth anatomy and vertical dimension can become serious consequences.[2,3] Considering the irreversible nature of this condition, early diagnosis and management by implementation of preventive and therapeutic measures are of utmost importance. In this regard, regular application of fluoride (F) products intended to reduce the solubility of the tooth surfaces has been one of the most recommended approaches.[4,5] However, previous studies show a large variation in efficacy, which among other factors seems to be strongly related to the type of F compound tested.[6–8]

The formation of calcium fluoride (CaF_2)-like deposits on the tooth surfaces is assumed to be the main mechanism of protection against dental erosion provided by conventional F compounds, such as sodium fluoride (NaF) and amine fluoride (AmF).[8] These deposits can act either as a physical barrier against erosive acids or as a mineral reservoir for remineralization.[9] Nevertheless, comparative studies showed that some F compounds with polyvalent metal cations, such as stannous fluoride (SnF_2) have improved efficacy.[6,8,10] Besides the formation of CaF_2, the stannous ion (Sn) can interact with the tooth surfaces forming a Sn-rich coating, which may also be relevant for erosion prevention.[6,8,11] Previous in vitro and in situ studies on solutions containing F and Sn (F as NaF and AmF; Sn as $SnCl_2$ – stannous chloride) seem to suggest an additive effect between these ions.[12,13]

Organic and inorganic polymers have also been evaluated for their ability to reduce dental erosion. Some polymers have been tested as active ingredients of rinse solutions or toothpastes[5,14–16] and also as additives in acidic beverages.[17–21] The tested polymers have shown the potential to reduce erosion progression due to their ability to adsorb to the dental surfaces, leading to the formation of a protective film. Promising results were obtained especially for milk casein,[15] chitosan,[5] linear sodium polyphosphate (LPP)[17,18,21] and a combination of carboxymethylcellulose, xantham gum and copovidone.[14] In addition, previous studies have demonstrated that several of these polymers can interact positively with fluoride compounds, thereby enhancing its protective effects.[5,15,22]

There is, however, considerably more scope for further research as (a) none of the tested film-forming agents or combinations thereof have been shown to completely inhibit erosion, and (b) research to determine additive or synergistic anti-erosive properties of combinations of actives has been very limited. Therefore, the present study was concerned with the investigation of the anti-erosive properties of some of the above mentioned film-forming agents, and especially in their interaction with fluoride. The pH-stat method (Phase 1) was used as a first screening tool. The most promising test solutions were then further evaluated using two in vitro erosion cycling models of different aggressiveness (Phase 2a and 2b). Our test hypothesis was that the additives, alone or in combination with F would present improved anti-erosive potential, when evaluated under different erosive conditions.

2.   Materials and methods

2.1.   Experimental design

This study was carried out in 2 phases. In Phase 1, hydroxyapatite crystals were exposed to solutions containing F (as NaF), phosphate polymers, proteins and Sn (as $SnCl_2$); as well as some of their combinations. Deionized water was used as negative control (C). The crystals were then tested in triplicate with the pH-stat as a screening method, using a standard citric acid solution (0.3%, pH = 3.8). The agents with the most promising results in Phase 1 (F, LPP, Sn), some of their combinations and the control were tested in Phase 2 in two independent experiments (2a and 2b), following a factorial 8×2 design, with rinse solutions and tooth substrates as the two experimental factors. Both experiments consisted of an erosion–remineralization cycling model using enamel and dentine specimens ($n = 10$ for each substrate). In experiment 2a, erosion was performed with 0.3% citric acid (pH = 3.8). In 2b, a more aggressive challenge with the use of 1% citric acid (pH = 2.4) was carried out. The response variable for phase 1 was the volume (ml) of the titrant (0.1 N HCl), which was converted to hydroxyapatite dissolution (in mg). For phase 2 the response variable was surface loss (SL in μm) measured by optical profilometry. To better understand the interaction between F, LPP and Sn with the hydroxyapatite surface, an additional test was performed to determine the zeta potential of the dispersed HA particles treated with the solutions containing these agents isolated. Most particles in colloidal dispersions have an electrical charge on its surface. The zeta potential is the overall charge that a particle acquires in a particular environment. There are several mechanisms for the appearance of this surface charge depending on the nature of the particle and the surrounding medium. The main mechanisms are: (1) ionization of groups on the surface, (2) a differential ion loss of crystal lattice and (3) adsorption or precipitation of charged species. Thus, the determination of the zeta potential is important for the study of surface interactions.[23]

2.2.   Phase 1

In this phase, solutions of the following agents: sodium fluoride (F) (Sigma–Aldrich, St. Louis, MO, USA), sodium polyphosphate with an average chain length of 25 phosphate units, linear structure (LPP) (Calgon 696, Thermos Inc., Cheshire, UK); sodium tripolyphosphate (STP) (Sigma–Aldrich Co.); sodium pyrophosphate tetrabasic (PP) (Sigma–Aldrich Co.), sodium caseinate (SC) (Spectrum Chemicals, New Brunswick, NJ, USA), albumin from bovine serum (BSA) (Sigma–Aldrich Co.), stannous chloride (Sn) (Sigma–Aldrich Co.) and some of their combinations were prepared, creating the experimental groups described in Table 1. For F, the concentration that is usually found in oral rinse products (225 ppm or approximately 0.5 g/l) was chosen.[24] For the