DENTAL MATERIALS XXX (2017) XXX–XXX

Available online at www.sciencedirect.com

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An interproximal model to determine the erosion-protective effect of calcium silicate, sodium phosphate, fluoride formulations

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ARTICLE INFO

Article history:
Received 19 May 2017
Received in revised form
10 November 2017
Accepted 13 November 2017
Available online xxx

Keywords:
Erosion
Calcium phosphate sodium silicate
Enamel
Interproximal model
Toothpaste

ABSTRACT

Objectives. Previous work has shown the effectiveness of a newly developed interproximal model to differentiate between the amount of remineralization caused by toothpastes used with or without a dual-phase gel treatment system containing calcium silicate, sodium phosphate salts and fluoride to repair acid-softened enamel. The aim of this study was to utilize the same interproximal model to identify how effective calcium silicate phosphate toothpastes are at reducing surface softening in the early stages of erosion. The model was also used to identify the effect of increasing the frequency of acid exposure on the reduction in surface hardness.

Methods. Human enamel specimens were prepared and mounted in an interproximal face-to-face arrangement and exposed to a cycling regime of whole human saliva, treatment, artificial saliva and 1% citric acid pH 3.75. Specimens were measured by surface microhardness at baseline and after three and seven days. The frequency of acid exposure was increased from 2 to 4 cycles a day for the second part of the study.

Results. The results showed that specimens treated with the calcium silicate phosphate toothpastes softened less than those treated with control fluoridated or non-fluoride toothpastes at each time point and following an increase in the frequency of acid exposure.

Significance. This work has demonstrated how an interproximal model can also be successfully used to determine differences in the erosion protection of various treatments as well as determining how they perform when the frequency of acid exposure is increased.

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https://doi.org/10.1016/j.dental.2017.11.017

1. Introduction

Within the oral cavity dental hard tissues are exposed to many factors that could lead to wear and mineral loss [1]. Dietary acids, such as those found in soft drinks, are a very common cause of enamel erosion within the mouth; the most prevalent of which is citric acid [2].

The investigation of dental erosion has increased dramatically over the last fifteen years and for reasons of reproducibility and ease of measuring most of the *in vitro* work has been carried out on flat, polished enamel surfaces in an open environment with a free flow of solution around the enamel specimen [3]. It could be argued that this does not fully represent the environment in the oral cavity as within the oral cavity there are several crevices and interproximal areas where the fluid flow around the region is not as freely flowing as in an open environment. The enamel found at the interproximal region of the tooth is exposed to a unique environment, when compared to the buccal/labial or the lingual/palatal surfaces, due to the potential confinement of bacteria and/or acidic food and drinks next to the tooth surface within the interdental space [4,5]. The space below the interdental point varies from tooth to tooth and can be as much as 6 mm in length down to the cemento enamel junction [6] where the enamel thins into nothing thus making it more susceptible to enamel loss and subsequent pain caused by sensitivity [7]. Until recently, the only *in vitro* interproximal models were designed to simulate caries; however, it is also clinically relevant to determine the effect of erosive acid exposure on these potentially more vulnerable regions, especially as little is known about this. An *in vitro* interproximal erosion model has previously been described in the literature and been used to successfully demonstrate the remineralization effect of certain toothpastes on previously demineralized enamel, when mounted interproximally [8]. The model consisted of individual bovine enamel pieces mounted so that exposed enamel surfaces were set face-to-face with an approximate 100 μm space between both pieces of enamel to simulate the interproximal space and allow local reactions to take place that might also be taking place in the oral environment. This previous study highlighted a difference in the rate of remineralization observed when specimens in an open environment were treated with the same toothpastes as those using the interproximal model [9]. The magnitude of remineralization measured using the open environment model was greater than that observed using the interproximal model, thus highlighting the importance of further investigating the rate of erosion of specimens using the interproximal model.

It is known that the presence of calcium and phosphate in oral care products can increase the concentration of those ions in the saliva. These increased concentrations mean the saliva has a higher degree of saturation with respect to calcium and phosphate ions, reducing the rate of enamel dissolution induced by a low oral pH from the presence of extrinsic and/or intrinsic acids [10]. There have been many developments in toothpaste manufacturing to include agents that are effective in reducing dental erosion specifically, as this is recognized as requiring a different approach to that of dental caries [11–13]. A recently developed oral care product combines the use of calcium silicate, sodium phosphate salts and fluoride in a novel treatment system to help protect sound enamel from erosive attacks, while repairing acid-softened enamel [8,9,14,15]. The system involves the use of a calcium silicate and sodium phosphate salts plus fluoride containing toothpaste, in conjunction with a dual-phase gel used for 3 consecutive days, once a month. Enamel is protected and repaired through the deposition of calcium silicate which facilitates the nucleation of hydroxyapatite (HAP), the predominant mineral in teeth [14,16]. Tooth mineral loss from acid challenges has been shown to be significantly decreased by the application of calcium silicate and by the combined use of calcium silicate and fluoride [8,9,13].

The aim of this work was to employ the previously developed interproximal model to determine the effectiveness of calcium silicate, sodium phosphate salts and fluoride containing oral care products in reducing surface softening of human enamel *in vitro* and to identify the effect of increasing the frequency of acid exposure. The null hypotheses tested were (1) there are no differences in the amount of surface softening that takes place following treatment with each of the products tested at each time point and (2) an increase in the frequency of acid exposure does not influence the amount of surface softening of the enamel following treatment.

2. Materials and methods

2.1. *Preparation of enamel specimens*

Human molars sourced from a HTA licensed tissue bank (REC 11/NI/0145) were sectioned under irrigation into enamel specimens using a microslice (Ultratec, Santa Ana, CA, USA). The flattest surface of the sectioned enamel was briefly ground on a rotating polishing machine using a silicon carbide disc (p1200), to form a flat enamel face. These specimens were then embedded face down and slightly off center in resin (Stycast 1266, Hitek Electronic Material Ltd., South Humberside, UK). The blocks produced were subsequently ground flat using a silicon carbide disc (p1200), followed by polishing in a slurry of silica powder (p1200) (Kemet, Kent, UK) in deionized (DI) water on a glass slab, by hand, until the enamel surface was level and fully exposed. The samples were rinsed and then sonicated in DI water for 10 min, before being polished to a flat shine using a slurry of 0.3 μm alumina powder (Kemet, Kent, UK) and DI water, on a felt pad (Kemet, Kent, UK). The samples were again rinsed and sonicated in DI water for 10 min.

Baseline microhardness measurements were taken for all specimens; the specimens were then grouped such that each treatment group had a similar range of hardness values. Several specimens from each group were also subjected to SEM imaging, prior to experimentation. Following baseline measurements, the specimens were paired and attached together using double-sided tape so that the enamel faces were set face-to-face at an approximate distance of 100 μm apart. Pairs of blank resin blocks, *i.e.* containing no enamel specimens, were placed on both ends to ensure uniform exposure of the test specimens. Each group consisted of 8 specimen pairs (16 total specimens), and was subjected to a unique treatment regime.

Please cite this article in press as: Wood NJ, et al. An interproximal model to determine the erosion-protective effect of calcium silicate, sodium phosphate, fluoride formulations. Dent Mater (2017), https://doi.org/10.1016/j.dental.2017.11.017