Use of dentifrices to prevent erosive tooth wear: harmful or helpful?*

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Abstract: Dental erosion is the loss of dental hard tissues caused by non-bacterial acids. Due to acid contact, the tooth surface becomes softened and more prone to abrasion from toothbrushing. Dentifrices containing different active agents may be helpful in allowing rehardening or in increasing surface resistance to further acidic or mechanical impacts. However, dentifrices are applied together with brushing and, depending on how and when toothbrushing is performed, as well as the type of dentifrice and toothbrush used, may increase wear. This review focuses on the potential harmful and helpful effects associated with the use of dentifrices with regard to erosive wear. While active ingredients like fluorides or agents with special anti-erosive properties were shown to offer some degree of protection against erosion and combined erosion/abrasion, the abrasive effects of dentifrices may increase the surface loss of eroded teeth. However, most evidence to date comes from *in vitro* and *in situ* studies, so clinical trials are necessary for a better understanding of the complex interaction of active ingredients and abrasives and their effects on erosive tooth wear.

Descriptors: Tooth Erosion; Tooth Abrasion; Dentifrices.

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Introduction

Dental erosion is the loss of dental tissue caused by extrinsic (dietary or environmental) or intrinsic (gastric) acids. This loss occurs in a continuous process and two distinct phases can be distinguished. In the initial phase (erosion), enamel softening occurs without surface loss. Successive erosive attacks lead to surface loss in the advanced phase (erosive tooth wear), and the remaining surface is still softened.[1]

Although the ultimate causal agent for dental erosion are non-bacterial acids, in fact the etiology is multifactorial, involving a complex interaction among behavioral, chemical and biological factors.[2] Preventive measures for dental erosion are targeted against these causal factors and may include dietary intervention, modification of acidic drinks, behavioral changes and modification of the tooth surface to increase its resistance to acidic attacks.[3]

Among the preventive measures related to behavioral factors, oral hygiene habits are of special interest. Dentifrices containing different active agents may be helpful to allow rehardening and to increase the resistance of the eroded surface to further acids or mechanical impacts. However, dentifrices are applied together with brushing and, depending on how and when toothbrushing is performed, as well as the type of dentifrice and toothbrush used, dentifrices may either increase or decrease the degree of wear. The potential harmful and helpful effects of dentifrices containing different active ingredients and abrasivity on erosive tooth wear are discussed in this review.

Review of literature and discussion

Dentifrice abrasivity

Toothbrushing plays an important role in maintaining oral health, and fluoride exposure by dentifrices provides not only protection against caries, but also some protection against dental erosion. On the other hand, abrasive wear of sound and, especially, of eroded dental hard tissues is considered a potential adverse side effect of toothbrushing.[4] Erosive demineralization of enamel and dentin is accompanied by surface softening, which accounts for the increased susceptibility to abrasion, especially immediately after an erosive challenge.[5-7] However, at least for eroded dentin, increasing waiting periods prior to brushing probably facilitates rehardening of the surface and, thus, enhancement of abrasion resistance.[6] Alternatively, patients suffering from severe erosion may benefit by brushing their teeth immediately before rather than after an erosive attack to avoid abrasion of softened tissue.[8]

As shown for sound dental hard tissues,[9-11] toothbrushing abrasion of eroded enamel and dentin is mainly influenced by the abrasivity of the dentifrice and, to a lesser extent, by the toothbrush itself.[12,13] Depending on the characteristics of the toothbrush, such as type, filament stiffness, and filament end-rounding, the toothbrush as a delivery vehicle only modulates the abrasivity of the dentifrice.[11-13]

In vitro studies clearly demonstrated that abrasion of eroded enamel and dentin increased with increasing REA (relative enamel abrasion) or RDA (relative dentin abrasion) values, respectively, of the dentifrice.[12-16] However, in the case of enamel, this effect was less pronounced when the abrasion of dentifrices with different abrasivity on eroded specimens was investigated *in situ*.[17,18] A possible explanation could be that over a short (clinically relevant) period of time, a softened layer of less than 0.5 µm thickness of eroded enamel is easily removed, independently of the abrasivity of the dentifrice.[19] In this context, it is worth mentioning that toothbrushing abrasion of eroded dental hard tissues is also related to brushing force, but these aspects are discussed in detail elsewhere.[20,21]

However, interpretation of dentifrice abrasivity studies is challenging, particularly because the REA or RDA values obtained from different sources may vary distinctly.[22] Moreover, the relationship between enamel abrasion (REA) and dentin abrasion (RDA) is not necessarily direct, *e.g.*, a dentifrice with a high RDA value may have a relatively low REA value and vice versa.[11,18] On this basis, interpretation of a recent study analyzing the abrasive potential of new anti-erosion dentifrices on eroded enamel is difficult, since only RDA and not REA values were given.[22] However, RDA values of the special-formulation dentifrices were in the range of conventional dentifrices, which may account for the fact that the special formulations were not superior, and may even be less effective in preventing enamel erosion-abrasion.

The abrasion of eroded enamel and dentin increases with increasing abrasivity of the dentifrice,[13,23] thus dentifrices with high abrasivity, such as whitening dentifrices, should not be used on a frequent basis.[17]

Active ingredients in dentifrices

Since dentifrices are widely used for oral hygiene and prevention of dental caries,[24] it is evident that they should also be used as a vehicle for protective ingredients against dental erosion.[25]

One of the most common active ingredients found in dentifrices is fluoride. Different fluoride compounds have been used, such as NaF (sodium fluoride), MFP (sodium monofluoride phosphate), SnF_2 (stannous fluoride) and AmF (amine fluoride). Fluoride concentrations in dentifrices typically vary between 550 and 1450 ppm F. However, recent studies have shown a limited beneficial effect of conventional 1100 ppm F dentifrices (NaF) compared with non-fluoridated dentifrices with regard to abrasion of eroded dentin and enamel (an approximate

30% reduction in wear when compared with a placebo).[26,27]

Based on these findings, highly concentrated fluoride dentifrices (5000 ppm F, NaF) have been tested, but the results obtained so far are inconclusive. In an *in situ* study, a commercial dentifrice with 5000 ppm F had the same positive effect as another commercial 1100 ppm F dentifrice (NaF) on eroded and eroded-abraded dentin.[28] With respect to enamel, no significant differences were found among 0, 1100 and 5000 ppm F dentifrices on erosion and erosion-abrasion *in situ*.[29] In contrast, an experimental 5000 ppm F dentifrice was able to significantly reduce enamel erosion and erosion-abrasion compared to a conventional 1100 ppm F dentifrice *in vitro*.[30] It has been discussed that the amount of fluoride available in the dentifrice slurry is not directly related to the possible protective effect of dentifrices against enamel erosion.[22] Therefore, the effect of highly concentrated fluoride dentifrices on dental erosion and abrasion is still under debate.

Regarding the type of fluoride compound, most of the studies were conducted using NaF dentifrices. It is believed that the mechanism of action of fluoride against erosion occurs by inducing the formation of a layer on the eroded surface, which is composed of CaF_2 (in the case of conventional compounds, such as AmF or NaF) or of metal-rich surface precipitates (in the case of SnF_2). These layers should behave as a physical barrier, hampering the contact of acid with the underlying enamel, or as a mineral reservoir that is attacked by the erosive challenge, thus buffering the acids or promoting mineral precipitation.[31] However, fluoridation by dentifrices is less effective in preventing enamel and dentin erosion than intensive fluoridation with the additional use of fluoridated gels and rinses.[32]

The use of tin-containing fluoride products seems to provide the best approach for effective prevention of dental erosion compared with conventional fluorides, such as NaF.[31,33,34] SnF_2 dentifrices markedly reduced the dissolution of teeth *in vivo*, whereas NaF dentifrices provided no protection.[35] More recently, SnF_2 dentifrices were shown to be superior in reducing dental erosion when compared with NaF dentifrices, but not combined erosion and abrasion,[22] although another study showed that SnF_2-containing dentifrices significantly reduced erosive and abrasive wear compared to NaF dentifrices.[36] Thus, evidence available so far suggests that SnF_2 seems to be the best fluoride salt that should be incorporated into dentifrices for preventing erosion and abrasion, at least for enamel. Moreover, when new formulations aimed at preventing erosion are developed, the possible interaction among the different components should be considered. It was reported that the combination of NaF with the desensitizing agent KNO_3 impairs the effect of fluoride on the reduction of wear.[37]

It is important to bear in mind that other factors such as pH, consistency and abrasivity may modulate the effect of fluoride dentifrices on dental erosion and abrasion. In a recent study it was shown that fluoride concentration and consistency influenced enamel and dentin wear, while the pH seemed to have no effect,[38] as had been previously shown for commercial dentifrices with pH ranging between 4 and 7.[39] In addition, the effects of fluoride may be partly masked by the abrasivity of the dentifrice.[14,38] Some reduction of available ions (tin) may occur in dentifrices due to their adsorption to the negatively charged silica.

Recently, new dentifrices claiming anti-erosive properties have been marketed, but few studies have evaluated their effectiveness so far. These new dentifrices usually contain KNO_3 (anti-hypersensitivity agent), hydroxyapatite (HAP) with or without fluoride, Zn-carbonate hydroxyapatite, calcium sodium phosphosilicate (remineralizing agents) and chitosan.

Dentifrices containing NaF and 5% KNO_3 have shown potential to reharden eroded enamel surfaces;[40-42] however, for the prevention of enamel erosive wear, they have almost no effect compared to placebo.[2,37,43] This may be due to the interaction between NaF and KNO_3, which reduces the bioavailability of fluoride.[37]

Remineralizing agents, such as hydroxyapatite (with or without F) and Zn-carbonate hydroxyapatite, are expected to induce some mineral precipitation on enamel.[44] However, the incorporation of new hydroxyapatite into demineralized enamel is not able to increase the resistance to erosive dissolution.[22] The same was shown for calcium sodium phosphosilicate. Although it was deposited on enamel and on dentin surfaces as well,[45] this either had no preventive or repairing effect on erosion[46] or the effect against erosion was similar to that of conventional fluoride dentifrices.[47] Therefore, so far there is no evidence that the incorporation of salts that could be converted into hydroxyapatite or that the direct incorporation of hydroxyapatite or nano-hydroxyapatite into dentifrices significantly contributes to reduce enamel solubility under erosive challenges.[22]

Chitosan is a natural polysaccharide produced by deacetylation of chitin. It presents a positive charge at a low pH, readily adsorbing to enamel.[48] It is speculated that chitosan can build up a protective organic layer through interaction with enamel and proteins from the acquired pellicle.[49,50] Moreover, due to its lubricating effects, it may reduce the abrasivity of dentifrices by binding to the silica particles or the tooth surface.[51] Therefore, chitosan may also enhance the effect of stannous fluoride–containing dentifrices, which were shown to have a distinct anti-erosive effect on enamel and dentin.[51] However, the inclusion of chitosan in non-fluoridated dentifrices did not show further protective effects against enamel erosive wear compared to conventional fluoride dentifrices.[22]

Other dentifrices, containing arginine and strontium, have been recently marketed as anti-hypersensitivity products, but nearly no study has so far been conducted to evaluate their potential against dental erosion. Strontium acetate and arginine-based dentifrices resulted in significant dentin tubular occlusion, but the arginine-based dentifrice was more susceptible to acid challenge compared to strontium. Both dentifrices presented behavior similar to that of a placebo with respect to acid resistance.[52] On the other hand, strontium-containing dentifrices were shown to have better efficacy in occluding dentinal tubules compared to arginine-based dentifrices, which may be an indication of better effectiveness against erosion.[53]

Conclusion

To date, most of the information regarding the use of dentifrices to prevent erosive tooth wear comes from *in vitro* and *in situ* studies, so the available evidence has to be confirmed by further clinical studies.

From the available literature, it can be concluded that the possible benefits of dentifrices exceed adverse side effects by far, not only because active ingredients for the prevention of erosion and—more importantly—caries can be included, but also because their abrasives ensure biofilm removal and tooth cleaning.

In the case of dental erosion, various active ingredients have been tested so far, which ideally act by forming acid-resistant surface precipitates. While studies proved that fluoridated dentifrices offer some degree of protection, most of the other potential active ingredients have hardly been investigated so far, so no final conclusions can be drawn. Abrasion effects are considered a potential side effect of dentifrices, but clinical studies did not prove the significance of toothbrushing abrasion on overall tooth wear. However, *in situ* studies indicate that the use of high abrasive dentifrices should be avoided to prevent further wear of eroded enamel and dentin.

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