

Do commercial whitening dentifrices increase enamel erosive tooth wear?

Abstract

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Objective: This *in vitro* study evaluated the effect of commercial whitening dentifrices on erosive tooth wear (ETW) of bovine enamel samples, in comparison with commercial regular dentifrices. **Methodology:** Sixty bovine crowns were embedded in acrylic resin, polished and then had their baseline profile determined. They were randomly assigned to 5 groups (n=12/group), according to the type of commercial dentifrice to be tested: GI – Crest Anti-cavity Regular; GII – Crest 3D White; GIII – Colgate Total 12 Clean Mint; GIV – Colgate Optic White; GV – Placebo (negative control, fluoride-free dentifrice). The samples were submitted to daily erosive and abrasive challenges for 3 days. The erosive challenges were performed 3 times a day by immersing the specimens in 0.1% citric acid solution (pH 2.5) for 90 s. Each day after the first and last erosive challenges, the specimens were subjected to the abrasive challenge for 15 s, using a toothbrushing machine (Biopdi, São Carlos, SP, Brazil), soft toothbrushes and slurry (1:3 g/ml) of the tested toothpastes (1.5 N). The specimens were kept in artificial saliva between the challenges. The final profile was obtained and the ETW (μm) was calculated. Data were analyzed by Kruskal-Wallis and Dunn's tests ($p < 0.05$). **Results:** All dentifrices tested significantly reduced the enamel wear in comparison with the Placebo, except GIII. The median (95% CI) ETW was 1.35 (1.25-1.46)^{bc} for GI, 1.17 (1.01-1.34)^{cd} for GII, 1.36 (1.28-1.45)^{ab} for GIII, 1.08 (1.04-1.14)^d for GIV and 2.28 (2.18-2.39)^a for GV. **Conclusion:** When dentifrices from the same manufacturer were compared, the whitening dentifrices led to similar or less wear than the regular ones.

Keywords: Tooth erosion. Toothpastes. Tooth bleaching agents. *In vitro* techniques.

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Introduction

Erosive tooth wear (ETW) is the loss of dental hard tissue caused by the interplay between the exposure to nonbacterial acids and abrasive forces, and the action of these acids is its primary etiological factor.¹ Due to its increasing prevalence² and adverse consequences, ETW has been a matter of concern in the dental community in the last decades,^{3,4} and appropriate preventive measures must be implemented for high risk patients.⁵

The evidence on the efficacy of fluoridated dentifrices to prevent ETW is much less clear⁶ than it is for caries prevention.⁷ This may be related to the lack of clinical studies on the topic but also to the fact that the erosive challenge is stronger than the carious one due to the lower pH of the dietary and intrinsic acids compared with the bacterial acids.⁸ Moreover, dentifrices are used during brushing, which means that depending on how toothbrushing is performed and on type of dentifrice and toothbrush, dentifrices may either increase or decrease the wear degree.^{9,10}

Considering that abrasion of eroded enamel increases with increasing abrasivity of the dentifrice,^{11,12} dentifrices with high abrasivity should not be used by patients at high risk for ETW.^{9,13} From the practical point of view, following this recommendation is very difficult for the patients, since information on the abrasivity of the dentifrices is not available on the labels of the product. The general advice is to avoid whitening dentifrices,⁹ which might have higher abrasivity in order to optimize the removal of extrinsic stains.¹⁴ However, information on the association between the use of whitening dentifrices and the increased ETW are contradictory. While some studies have reported higher ETW degrees when whitening dentifrices are used compared with conventional ones,^{15,16} others have not.^{17,18} Moreover, a recent study showed a distinct abrasive potential for whitening dentifrices with different technologies, such as disodium pyrophosphate, "blue light", tetrasodium pyrophosphate and tetrapotassium pyrophosphate.¹⁹ These inconsistencies in the literature might occur due to the fact that whitening products act via the presence of abrasive, chemical, or optical agents, alone or in combination.²⁰ For this reason, studies evaluating the effect of whitening dentifrices on ETW are necessary, since new products are launched into the market. Thus, this *in vitro* study sought to evaluate

the effect of commercial whitening dentifrices on ETW of bovine enamel samples compared with regular commercial dentifrices. The null hypothesis tested was that brushing with the whitening dentifrices does not increase the ETW degree in comparison with the regular dentifrices.

Methodology

Preparation of enamel specimens

Sixty enamel specimens were prepared from freshly extracted bovine incisors that had been stored in 0.1% thymol solution (pH 7). The crown and root were separated using a cutting machine (Maruto, Kasuga, Tokyo, Japan) and a diamond disc (Maruto, Kasuga, Tokyo, Japan). The crowns were coupled to a prefabricated silicone mold (Biopdi, São Carlos, São Paulo, Brazil) and embedded in auto polymerizing acrylic resin with the labial surface exposed. After polymerization, the samples were polished using silicon carbide sandpapers (320, 600 and 1200 grades of Al₂O₃ papers; Buehler, Lake Bluff, Illinois, USA) and cleaned for 5 minutes in deionized water by sonication (Ultrasound T7 Thornton, Unique, Indaiatuba, São Paulo, Brazil), with a frequency of 40KHz. Then the baseline profile was measured using a contact profilometry. Thereafter, 2/3 of the surfaces of the specimens were protected with nail polish (Risqué, São Paulo, São Paulo, Brazil), to obtain two control areas (at the outer thirds of the specimens), leaving the central third free.

The enamel specimens were randomly distributed (using Microsoft Excel) into 5 groups of 12 specimens each, according to the type of commercial dentifrice to be tested: GI – Crest Anti-cavity Regular (Procter & Gamble, Cincinnati, Ohio, USA); GII – Crest 3D White (Procter & Gamble, Cincinnati, Ohio, USA); GIII – Colgate Total 12 Clean Mint (Colgate-Palmolive, Piscataway, NJ, USA); GIV – Colgate Optic White (Colgate-Palmolive, Piscataway, NJ, USA), GV – Placebo (negative control, fluoride-free dentifrice, Europharma Concepts Ltd., Lehigh, Clare, Ireland). The composition of the dentifrices is described in Figure 1. Briefly, the dentifrices in groups I to IV are fluoridated and the dentifrice in group V is fluoride-free (negative control). In groups I and II both dentifrices were manufactured by Procter & Gamble, being I and II regular and whitening dentifrices, respectively.

Similarly, dentifrices III and IV were manufactured by Colgate, being III and IV regular and whitening dentifrices, respectively. Sample size calculation was based on the study by Moron, et al.²¹ (2013). Considering the mean and SDs of placebo and 1100 ppm fluoride dentifrices, a sample size of 11 specimens would be required to obtain an $\alpha=5\%$ and $\beta=80\%$.

Erosive-abrasive cycles and treatments

The specimens were subjected to daily erosive and abrasive challenges for 3 days. The erosive challenges were performed 3 times a day by immersing the specimens in 0.1% citric acid solution (pH 2.5, 30 mL/sample) for 90 s min at 25°C under gentle agitation.²² The samples were then washed with deionized water (10 s) and immersed for 2 h in artificial saliva²³ (pH 6.8, 30 mL/sample) at 25°C for 2 h between the erosive challenges.

Each day shortly after the first and last erosive challenges, the specimens were subjected to the abrasive challenge for 15 s, using a toothbrushing machine (Biopdi, São Carlos, São Paulo, Brazil), soft toothbrushes (5460 ultrasoft Curaprox®, Kriens, Switzerland, 1 toothbrush/sample) and slurry of the tested toothpastes in water (1:3 g/ml) with final volume of 15 mL/sample, under standardized speed (3 linear movements/s) and force (1.5 N), at 37°C.^{19,24} The specimens were maintained in artificial saliva overnight to complete a 24 h cycle. The citric acid was renewed at each erosive challenge and the artificial saliva was daily replaced by a new one.

After 3 days, the nail varnish was removed with

commercial acetone and the final profile was obtained to provide the ETW calculation.

Contact profilometry

The ETW was measured using a contact profilometer (Mahr Perthometer, Göttingen, Germany). Five equidistant surface scans of each sample were performed (5 mm of reading, 250 μm apart, area: 5 mm²) at the baseline and after the experimental period. To allow repeatability, the samples had an identification mark (small drillings made with 1/4 bur) and two scratches delimitating the exposed area. They were inserted into a metal device (x and y axes determination, reproducibility 0.08 μm), to allow the accurate stylus repositioning at each measurement. The baseline profile was compared with the final one using the software Marh Surf XCR20 for the enamel loss calculation. The scans were superposed, and the average depth of the under-the-curve area was calculated (μm).

Statistical analysis

The GraphPad InStat software for Windows version 3.0 (GraphPad software Inc., La Jolla, CA, USA) was used. The data were analyzed by Kruskal-Wallis and Dunn's test after testing the equality of variances and normal errors distribution. The significance level was set at 5%.

Figure 1- Composition of the dentifrices evaluated

Groups	Commercial name (Manufacturer)	Whitening component	Composition (as stated on the labels)
GI	Crest Anti-cavity Regular (Procter & Gamble)	no	Sodium fluoride (1500 ppm fluoride), sorbitol, water, hydrated silica , sodium lauryl sulfate, trisodium phosphate, flavor, sodium phosphate, cellulose gum, sodium saccharin, carbomer, titanium dioxide, color
GII	Crest 3D White (Procter & Gamble)	yes	Sodium fluoride (1500 ppm fluoride), water, sorbitol, hydrated silica , <u>disodium pyrophosphate</u> , sodium lauryl sulfate, flavor, cellulose gum, sodium hydroxide, sodium saccharin, carbomer, mica, titanium dioxide, color
GIII	Colgate Total 12 Clean Mint (Colgate-Palmolive)	no	Sodium fluoride (1450 ppm fluoride), triclosan, water, glycerin, sorbitol, hydrated silica , PVM/MA copolymer, sodium lauryl sulfate, cellulose gum, flavor, carragenan, sodium saccharin, sodium hydroxide, propylene glycol, titanium dioxide
GIV	Colgate Optic White (Colgate-Palmolive)	yes	Sodium monofluorophosphate (1300 ppm fluoride), propylene glycol, calcium pyrophosphate , glycerin, PEG/PPG-116/66 copolymer, PEG-12, PVP, silica , flavor, sodium lauryl sulfate, <u>tetrasodium pyrophosphate</u> , <u>hydrogen peroxide</u> , <u>disodium pyrophosphate</u> , sodium saccharin, sucralose, BHT
GV (negative control)	Placebo (Europharma Concepts Ltd.)	no	Sorbitol, water, hydrated silica , PEG-32, sodium lauryl sulfate, cellulose gum, flavor, sodium saccharin, monosodium phosphate, titanium dioxide.

Abrasive components are highlighted in bold. Chemical whitening components are underlined.

Table 1 - Median wear of enamel (μm) after treatment with dentifrices containing whitening components or not

Dentifrice	Fluoride/Whitening	Median wear (95% CI)	Mean of Ranks
Crest Anti-cavity Regular	1500 ppm (NaF)/No	1.32 (1.25-1.46) ^{bc}	33.33
Crest 3D White	1500 ppm (NaF)/Yes	1.11 (1.00-1.38) ^{cd}	15.63
Colgate Total 12 Clean Mint	1450 ppm (NaF)/No	1.31 (1.28-1.45) ^{ab}	36.09
Colgate Optic White	1300 ppm (MFP)/Yes	1.08 (1.04-1.14) ^d	11.96
Placebo	No/No	2.28 (2.18-2.39) ^a	53.50

Values followed by distinct superscripts are significantly different (Kruskal-Wallis and Dunn's test, $p < 0.05$). $n = 12$

Results

All tested dentifrices, except Colgate Total 12 Clean Mint, significantly reduced the enamel wear in comparison with the Placebo (Table 1). The lowest wear was found for the Colgate Optic White that performed significantly better than the other dentifrices, except for the Crest 3D White. When dentifrices from the same manufacturer were compared, the whitening dentifrices led to similar or less wear than the regular ones.

Discussion

This study was developed based on the increased concern regarding ETW⁴, the recommendation to at-risk patients on avoiding the use of whitening dentifrices due to their potentially increased abrasivity,^{9,13} and the contradictory results found in the literature regarding the abrasive potential of these dentifrices.¹⁵⁻¹⁹ According to the results of this study, the null hypothesis was accepted, since brushing with the evaluated commercial whitening dentifrices did not increase the enamel wear degree in comparison with the regular ones. In fact, the commercial whitening dentifrices led to similar or less wear when compared with the regular commercial dentifrices.

The model of this study involved an *in vitro* erosive-abrasive pH-cycling design, using bovine enamel specimens. Bovine teeth, despite less mineralized,²⁵ are easier to obtain and are regarded as suitable substitutes for human teeth in studies with protocol similar to this one.^{26,27} To simulate extrinsic erosive demineralization, the specimens were immersed for 90 s in 0.1% citric acid solution (pH 2.5), following previous studies.^{19,28} Some studies, especially those conducted years ago, employ longer exposure times, such as 5²⁹ or even 10 min.³⁰ However, shorter periods, such as the one employed in this study, are more

appropriate since they are able to demineralize the enamel without changing the degree of saturation of the solution and/or its pH value,³¹ simulating a mild erosive challenge. The erosive challenges were performed for 3 days, 3 times *per day*. In previous studies, the erosive challenges were conducted for longer periods (5-7 days),^{19,28} but in this study significant differences could be observed at 3 days, using profilometry as a response variable between the placebo dentifrice and the commercial ones. The abrasive challenge employed in this study was mild (45 linear movements during 15 s, under a 1.5 N force), similarly to other studies.^{19,24} In fact, wide variation is found in the literature regarding the number of movements and the brushing force, but reducing the duration and frequency of abrasion to better simulate the clinical condition is advised,³¹ which is in-line with this study. In fact, a previous study assessed 4 healthy volunteers' habitual toothbrushing force and the average force (\pm SD) was 1.50 ± 0.05 N.²⁴ Regarding the number of movements, a recent video observation study evaluating the brushing motion patterns in adults revealed that mean brushing duration was 135 s, predominantly on vestibular surfaces, but the volunteers tended to move frequently (35 times between the sextants).³² This means that the number of strokes employed in this study (45 during 15 s) is within what is expected in the clinical condition, considering only one surface. Moreover, the abrasive challenges were performed twice a day to simulate the clinical condition, since most people brush their teeth twice a day. It is also important to mention that this study used an ultrasoft toothbrush (5460 Curaprox). There was no special reason for this besides the fact that similar studies have been using it.¹⁹ However, this might have not influenced the pattern of results, since the toothbrush filament stiffness, at least for enamel, plays only a very minor role in ETW.^{10,11}

Among the active ingredients in the dentifrices evaluated, all the commercial ones had fluoride (range between 1300 and 1500 ppm), as sodium fluoride

(NaF) or sodium monofluorophosphate (MFP). In fact, the effect of monovalent fluoride compounds in the dentifrices to reduce erosion and abrasion is limited, with more promising results obtained for SnF₂-containing dentifrices.^{9,33} Interestingly, the lowest wear was found for the MFP-containing dentifrice. However, this effect was not related to MFP, since this study did not use any technique to break the covalent bond between fluoride and phosphate, which means that the amount of available fluoride was negligible.³⁰ Thus, the presence of fluoride in the tested dentifrices in this study might not explain the differences found between the distinct formulations. Regarding the commercial non-whitening dentifrices, the inclusion criteria were to have dentifrices most commonly used from both manufacturers. In addition, since this study had, from the same manufacturer, one whitening and one non-whitening dentifrice, as a negative control a fluoride-free dentifrice was included, despite the role of fluoride against ETW is not as well established as that against caries.⁸ Other options for negative controls would be not to brush (erosion only)¹⁹ or brushing with water (to reveal the effect of toothbrush filament stiffness). However, it has been shown that the abrasivity of the dentifrice is more important than the toothbrush filament stiffness, at least for the enamel.^{10,11}

Whitening dentifrices contain abrasive and whitening agents to remove extrinsic stains from the tooth surface. All the dentifrices evaluated, including placebo, had silica as abrasive agent. However, the number of abrasive agents, as well as the size, hardness and shape of the particles, are unknown since information regarding RDA/REA is not displayed on the labels. These elements are determining factors in the degree of abrasivity³⁴, and not knowing this information became a limitation of this study. No linear relationship is observed between the amount of silica present in the dentifrices and the degree of enamel loss under erosive and abrasive conditions.³⁵ It was recently shown that for dentifrices containing fluoride and tin, tissue loss increases up to a silica content of 10% but decreases significantly with higher amounts (20% silica is similar to the silica-free formulation).³⁵

The whitening agent present in the commercial whitening dentifrices is pyrophosphate, but Colgate Optic White also contains hydrogen peroxide. While some studies report that dentifrices containing silica and pyrophosphate lead to greater enamel wear in comparison with silica-only dentifrices,^{15,16,19} the

results of other studies^{17,29,36} agree with this one. The contradictory results might be explained by the distinct protocols employed in different studies. Regarding the studies that found a higher degree of wear for the dentifrices containing silica and pyrophosphate in comparison with those containing silica-only: one employed more concentrated slurry (1 part of dentifrice for 2 parts of water),¹⁶ the other employed longer erosion and abrasion cycles¹⁹ and another one was conducted *in situ* testing both sound and softened enamel.¹⁵ Interestingly, there was no difference between regular and whitening toothpastes for eroded enamel in the latter study, while for sound enamel the whitening dentifrice significantly increased the enamel wear.¹⁵ The study by Mosquim, et al.¹⁹ (2017) had a very similar protocol to that of this study, despite the erosive cycles, which were performed for 7 days. Interestingly, in the study by Mosquim, et al.¹⁹ (2017), whitening dentifrices containing silica and pyrophosphate led to higher ETW than the dentifrices containing silica-only. One could speculate that the absence of difference in the degree of wear between whitening and conventional commercial dentifrices in this study is due to the shortest period of erosive and abrasive challenges. However, in the *in situ* study by Joiner, et al.³⁶ (2008) the higher degree of ETW found for whitening dentifrices in comparison with conventional ones at 4 weeks was not observed at the 12-week evaluation.

Conclusion

In conclusion, the results of this study do not support the assumption that brushing with whitening dentifrices increases the degree of ETW in comparison with regular dentifrices. Thus, the recommendation that patients at high risk for ETW should avoid the use of whitening dentifrices lacks support in the current literature. Additional studies using methodologies that more closely resemble the clinical condition should be conducted to add evidence on this matter, considering the increasing concern regarding ETW.

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Author' Contributions

Simões, Ana Clara Correa Duarte: Data curation (Lead); Funding acquisition (Lead); Investigation (Equal); Methodology (Supporting); Writing-original draft (Equal); Dionizio, Aline: Data curation (Equal); Investigation (Equal); Methodology (Lead); Writing-original draft (Equal) Writing-review & editing (Equal) Câmara, João Victor Frazão: Data curation (Supporting); Methodology (Supporting); Sabino-Arias, Isabela Tomazini: Data curation (Supporting); Methodology (Supporting); Ventura, Talita Mendes da Silva: Data curation (Supporting); Methodology (Equal); Levy, Flavia: Conceptualization (Equal); Methodology (Supporting); Buzalaf, Nathalia Rabelo: Data curation (Supporting); Batista, Thiago Beltrami Dias: Data curation (Supporting); Magalhães, Ana Carolina: Conceptualization (Equal); Methodology (Equal); Writing-review & editing (Equal); Groisman, Sonia: Conceptualization (Equal); Supervision (Supporting); Writing-original draft (Equal); Buzalaf, Marília Afonso Rabelo: Corresponding Author; Conceptualization (Equal); Methodology (Supporting); Supervision (Equal); Writing-review & editing (Equal).

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