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Effects of different toothpaste formulations on erosive tooth wear prevention: systematic review

Efeitos de diferentes dentifrícios na prevenção do desgaste dentário erosivo: revisão sistemática de literatura

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ABSTRACT

Objective: erosive tooth wear is a multifactorial condition that results in loss of dental hard tissue, caused by a chemical and mechanical process. This paper aims to carry out a systematic review presenting the effects of different toothpaste formulations on the loss of dental enamel surface *in vitro*. **Material and Methods:** the searches were performed in the databases PubMed, Web of Science, LILACS and Scielo. Articles published from 2010 to 2020 were filtered, without language restriction. Articles that included abrasion and erosion protocols were searched, as they were more similar to clinical reality, since toothpaste is applied through tooth brushing. The searches with descriptors and free terms on the topic resulted in 992 articles, however only 12 were within the search criteria. **Results:** the selected studies appointed that association of conventional fluorides (NaF) with metallic fluorides can be a promising strategy for the reduction of surface loss by erosive tooth wear. Toothpastes containing sodium fluoride, as well as tin without chitosan, showed a reduction in surface loss, considered sufficient for individuals with medium exposure to acids. In children's toothpastes, the one containing sodium fluoride showed a reduction in surface loss when compared to non-fluoride dentifrices. **Conclusion:** different protocols may result in less or greater loss of enamel surface, and methodological differences should be considered. To clarify the effects of dentifrices on erosive tooth wear, other properties of dentifrices should be investigated.

KEYWORDS

Erosive tooth wear; Tooth erosion; Fluoride; Toothpastes; Termo; Systematic review.

RESUMO

Objetivo: o desgaste erosivo é uma condição multifatorial que resulta em perda de tecido duro dentário, causado por um processo químico e mecânico. Este trabalho tem como objetivo realizar uma revisão sistemática de literatura apresentando os efeitos de diferentes formulações de dentifrícios na perda de superfície de esmalte dentário *in vitro*. **Material e Métodos:** a busca foi realizada nas bases de dados PubMed, Web of Science, LILACS e Scielo. Foram filtrados artigos publicados no intervalo de 2010 a 2020, sem restrição de idioma. Buscou-se artigos que incluíssem protocolos de abrasão e erosão, por mais se assemelhar a realidade clínica, uma vez que o dentifrício é aplicado através da escovação dentária. A busca com descritores e termos livres sobre o tema encontrou 992 artigos, entretanto somente 12 estavam dentro dos critérios da pesquisa. **Resultados:** os estudos selecionados apontaram que associação dos fluoretos convencionais (NaF) com os metálicos pode ser uma estratégia promissora para a redução de perda de superfície pelo desgaste dentário erosivo. Dentifrícios contendo fluoreto de sódio, assim como estanho sem quitosana, apresentaram redução na perda de superfície, sendo considerada suficiente para indivíduos com exposição média aos ácidos. Em dentifrícios infantis, aquele que continha fluoreto de sódio apresentou uma redução de perda de superfície quando comparado com dentifrícios sem fluoreto. **Conclusão:** diferentes protocolos podem resultar em menor ou maior perda de superfície de esmalte e as diferenças metodológicas devem ser consideradas. Para esclarecer os efeitos dos dentifrícios no desgaste erosivo, outras propriedades dos dentifrícios devem ser investigadas.

PALAVRAS-CHAVE

Desgaste dentário erosivo; Erosão dentária; Flúor; Dentifrício; Termo; Revisão sistemática.

INTRODUCTION

Erosive tooth wear is a multifactorial and irreversible condition caused by a chemical and mechanical process, not associated with bacteria, that results in loss of dental hard tissue [1,2]. The chemical erosion process occurs with the tooth surface softening through exposure to acidic substances in a frequent, severe way and for long periods to be considered a clinically significant risk [1,2]. The mechanical process, on the other hand, occurs when, affected by acids, the tooth surface becomes softer and more susceptible to abrasion. Abrasive mechanical forces remove the softened enamel and generates significant irreversible loss of hard tissue, which characterizes erosive tooth wear [1,3].

Substantial preventive measures should be proposed to patients, such as dietary advice aiming to reduce the frequency of acidic foods and drinks, intake of drinks with high concentrations of calcium, prophylactic measures with the application of fluoride agents, stimulation of salivary flow, use of medications for tamponade effect, and gently brushing with anti-erosion toothpaste [4-6].

Toothpastes feature active ingredients that protect against tooth decay and other oral diseases and conditions, such as erosive tooth wear. However, inadequate oral hygiene habits and the interaction between erosion and abrasion can increase wear. The combination of brushing with abrasive toothpaste is a relevant factor for erosive tooth wear [7].

High concentrations of fluoride have been shown to increase the abrasion resistance of eroded enamel and decrease the development of enamel erosion [8]. Fluorides prevent erosive demineralization due to the formation of a calcium fluoride layer that acts as a physical barrier or mineral reservoir. The formation of this layer depends on pH, concentration, type of fluoride and frequency of application, and the released calcium and fluoride increase the saturation level in relation to the enamel, besides preventing dissolution [9].

Monovalent and polyvalent fluorides offer little protection in situations of frequent acid challenges and require frequent applications [9,10]. In a systematic review that evaluated the effect of different types of fluoride and vehicles for *in situ* studies, Zanatta et al. [11] concluded that sodium fluoride (NaF) in toothpastes offer limited protection.

Polyvalent metallic compounds may be more effective to protect against erosive tooth wear if compared to conventional fluorides. For better results, active ingredients such as amine and tin fluorides, phosphates and biopolymers have been tested [12]. However, there is still no consensus on which toothpaste formulation has the best preventive action against erosive tooth wear. The objective of this work is to carry out a systematic review presenting the effects of different toothpaste formulations on the loss of dental enamel surface *in vitro*.

MATERIALS AND METHODS

This review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA).

Eligibility criteria

The question to be answered on this systematic review was: “What fluoride toothpaste has the better preventive effect against erosive tooth wear in enamel?”

P (Patients) = enamel samples.

I (Intervention) = Erosion and abrasion protocols with conventional fluoride toothpaste.

(Comparison) = Erosion and abrasion protocols with antierosion fluoride toothpaste.

(Outcome) = Surface loss.

Inclusion criteria: *in vitro* (laboratory) studies that evaluated the effect of fluoridated toothpastes in preventing enamel erosive wear, using profilometry as a method for surface loss assessment.

Exclusion criteria: clinical studies, studies that did not evaluate erosive tooth wear, studies that did not subject the samples to an abrasive challenge, studies that did not include dentifrice in any experimental group, studies that evaluated erosive tooth wear in dentin only, studies that evaluated erosion and attrition, and studies that employed surface loss assessment methodologies apart from profilometry.

Search strategy

The searches were performed in March 2021 in the electronic databases: PubMed, Web of Science, Latin American and Caribbean Literature on Health Sciences (LILACS) and Scielo. Articles published between 2010 and 2020 were filtered, without language restriction. The search strategy was made using descriptors and free terms on the topic, following the search rules of each platform. On Chart I the terms used in each database are detailed.

Selection of articles and data collection

Duplicates – articles present in more than one database – were considered only once. After searching the electronic databases, the articles were initially selected based on the title and later by the abstract. After selection by abstract, the articles were read in full to ensure that they met the eligibility criteria. All these steps were performed by two researchers (C.M.A. and S.C.N.) who discussed possible questions and reached a consensus on whether to include the articles. All data were collected and organized in a specific form.

RESULTS

The searches performed resulted in a total of 992 articles, with 790 remaining after duplicates´ exclusion. From these, 120 articles were selected by title, and subsequently, 29 by abstract. Twelve articles met the eligibility criteria and were fully read for data collection (Figure 1).

Table I describes the selected articles regarding the number of samples and type of samples (bovine, human enamel). Table II presented the data regarding erosive agent, protocol of erosive and abrasive cycles, and method of surface loss assessment.

Chart I - Search Strategies

PubMed	(Erosive Tooth Wear OR Tooth Erosion OR Erosion OR Enamel Erosion OR Dental Erosion OR Erosive lesion OR Erosive lesions OR Softening OR Tooth Wear OR Dental Wear OR Enamel wear OR Acid wear) AND (Fluorides OR Fluoride OR Fluorides, Topical OR Topical Fluorides OR Fluoride Toothpastes OR Toothpastes OR Fluoride Dentifrice OR Dentifrice OR Fluoride varnish OR Fluoride varnishes OR Tin Fluorides OR Stannous Fluoride OR SnF2 OR SnCl2 OR Stannous OR Stannous gel OR Tin Compounds OR Tin OR Acidulated Phosphate Fluoride OR APF OR fluorophosphate OR monofluorophosphate OR sodium phosphate OR Sodium Fluoride OR NaF OR Calcium Fluoride OR CaF2 OR TiF4 OR Tetrafluoride OR Tetrafluorides OR Titanium OR Amines OR Amine fluoride OR AmF OR amine fluoride gel) AND (in vitro OR In Vitro Techniques OR laboratorial studies)
Web of Science	TS=("Erosive Tooth Wear" OR "Tooth Erosion" OR "Erosion" OR "Enamel Erosion" OR "Dental Erosion" OR "Erosive lesion" OR "Erosive lesions" OR "Softening" OR "Tooth Wear" OR "Dental Wear" OR "Enamel wear" OR "Acid wear") AND TS=("Fluoride*" OR "Fluorides, Topical" OR "Topical Fluorides" OR "Fluoride Toothpastes" OR "Toothpaste*" OR "Fluoride Dentifrice*" OR "Dentifrice*" OR "Fluoride varnish" OR "Fluoride varnishes" OR "Tin Fluorides" OR "Stannous Fluoride" OR "SnF2" OR "SnCl2" OR "Stannous" OR "Stannous gel" OR "Tin Compounds" OR "Tin" OR "Acidulated Phosphate Fluoride" OR "APF" OR "fluorophosphate" OR "monofluorophosphate" OR "sodium phosphate" OR "Sodium Fluoride" OR "NaF" OR "Calcium Fluoride" OR "CaF2" OR "TiF4" OR "Tetrafluoride" OR "Tetrafluorides" OR "Titanium" OR "Amines" OR "Amine fluoride" OR "AmF" OR "amine fluoride gel") AND TS=("in vitro" OR "In Vitro Techniques" OR "laboratorial studies")
LILACS	(erosive tooth wear) OR (tooth erosion) OR (erosion) OR (tooth wear) OR (enamel erosion) AND (dentifrices) OR (toothpastes) OR (fluorides) OR (fluoride dentifrice) OR (tin fluorides) OR (stannous fluorides) OR (snf2) OR (sncl2) OR (acidulated phosphate fluoride) OR (APF) OR (fluorophosphate) OR (monofluorophosphate) OR (sodium phosphate) OR (sodium fluoride) OR (naf) OR (calcium fluoride) OR (caf2) OR (tif4) OR (tetrafluoride) OR (tetrafluorides) OR (titanium) OR (amines) OR (amine fluoride) OR (amf) AND (in vitro) OR (laboratorial studies) OR (in vitro techniques)
Scielo	(erosive tooth wear) OR (tooth erosion) OR (tooth wear) AND (dentifrices) OR (toothpastes) AND (in vitro) OR (in vitro techniques) OR (laboratorial studies)

Erosive challenges were performed with different soft drinks, concentrated orange juice, citric and hydrochloric acids, being citric acid the most frequently used (six studies). Erosive challenges ranged from 1.5 to 5 minutes. Abrasive challenges differed in application time (if before or after erosion, and if after the whole erosive challenge or interchangeably), duration and load.

Table III describes data collected from the selected articles as to the groups of dentifrices tested and the values of surface loss found in the different erosion and abrasion protocols.

Moretto et al. [8] showed that experimental toothpastes with high concentration of sodium fluoride (5000 ppm F) and low concentration of sodium fluoride associated with sodium trimetaphosphate had less enamel surface loss when compared to placebo (without fluoride), followed by toothpaste with regular concentration (1100 ppm F).

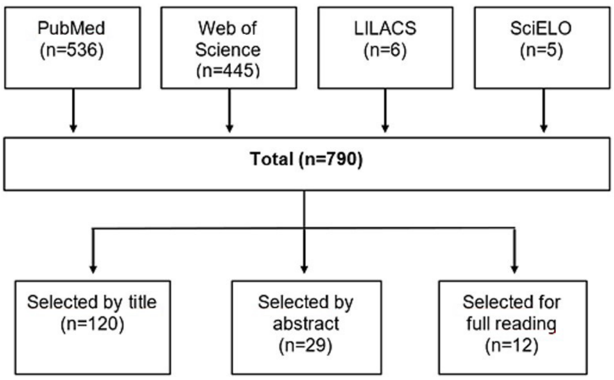

Figure 1 - Fluxogram showing strategy for articles search and selection.

Comar et al. [15] pointed out that the association of conventional and metallic fluorides may be a promising strategy to reduce surface loss by erosive tooth wear. Both experimental toothpastes (TiF4 and SnF2) and the commercial toothpaste ProHealth (SnF2+NaF) were similarly able to reduce surface loss [15].

Ganss et al. [16] analyzed the effectiveness of adding tin ion and chitosan in fluoride toothpastes. Toothpastes containing sodium fluoride, as well as those containing tin without chitosan, showed enough reduction in surface loss for individuals with average exposure to acids. Toothpastes containing tin and without chitosan showed similar amounts of fluorine and tin ions and presented similar results. When compared to the gel form in the control group, they showed less efficacy, which, according to the authors, was due to the lower amount of active ingredients available and the presence of abrasives [16].

Ganss et al. [13] demonstrated that the dentifrices evaluated had limited protection against abrasive brushing, and anti-erosion formulas were not superior and sometimes even less effective than conventional formulas. In addition, the toothpastes with tin content, when tested only through slurry (without abrasion), had its effect neutralized with brushing. The authors point out that due to methodological differences, the two experiments (only erosion and erosion followed by abrasion) could not be compared.

The study by Ganss et al. [18] demonstrated that among toothpastes containing sodium

Table I - Description of the selected articles regarding the number and type of samples

Author, year	Number of samples per group	Substrate type
1. Moretto, Magalhães, Sassaki, Delbem and Martinho (2010)	n=15	Bovine enamel
2. Ganss, Lussi, Grunau, Klimek and Schlueter (2011)	n=18	Human permanent enamel
3. Rochel, Souza, Silva, Pereira, Rios, Buzalaf and Magalhães (2011)	n=10	Bovine enamel
4. Comar, Gomes, Ito, Salomão, Grizzo and Magalhães (2012)	n=12	Bovine enamel and dentine
5. Ganss, Von Hinckeldey, Tolle, Schulze, Klimek and Schlueter (2012)	n=15	Human permanent enamel
6. Moron, Miyazaki, Ito, A Wiegand, Vilhena, Buzalaf and Magalhães (2013)	n=12	Bovine enamel and dentine
7. Ganss, Marten, Hara and Schlueter (2016)	n=15	Human permanent enamel
8. Mosquim, Souza, Foratori, Wang and Magalhaes (2017)	n=12	Bovine enamel
9. Soares, Magalhães, Fonseca, Tostes, Silva and Coutinho (2017)	n=20	Human permanent enamel
10. Wegehaupt, Schleich, Hamza, Wiedemeier and Attin (2018)	n=12	Bovine enamel
11. Simões, Dionizio, Câmara, Sabino-Arias, Levy, Ventura, Buzalaf, Batista, Magalhães, Groisman and Buzalaf (2020)	n=12	Bovine enamel
12. Passos, Sousa, Melo, Gomes, Santiago and Lima (2020)	n=8	Human deciduous enamel

Table II - Description of the articles regarding the erosive agent, protocol of erosive and abrasive cycles, and method of surface loss assessment

	Erosive agent	Erosive-abrasive cycle	Surface Loss Assessment Method
1. Moretto et al. [8]	Sprite, pH 2.8	7 days: 10 mL Sprite 4x/dia 5 min. Dentifrice treatment: 15s in the *slurry* dentifrice. Abrasion: 15s/load 30 g. Storage in 10 mL of artificial saliva pH 7.0 2h between cycles.	Contact profilometry 5 measurements and average (in micrometers)
2. Ganss et al. [13]	Citric acid pH 2.4	10 days: 250 mL citric acid 6x/day 2 min. Dentifrice treatment: immersion in 200 mL of the slurry for 2 min after the first and last erosive challenge. Abrasion: 15s during the 2 min immersion in the slurry, 200 g load. 150 oscillations/min. Storage in mineral salt solution pH 6.7 1.5h between cycles.	Optical profilometry 3 lines at intervals of 0.2mm and 2mm in length, 2 regression lines 0.5mm long on each line, tissue loss value referring to the vertical distance between regression lines in micrometers
3. Rochel et al. [14]	Coke pH 2.3	7 days: 30 mL Coke 4 x/day 2 min. Dentifrice treatment: immersion in 0.5 mL of the slurry for 15s after the first and last erosive challenge. Abrasion: 15s, 166 oscillations/second and 1.5N load. Storage in artificial saliva pH 6.8 2h between cycles.	Contact profilometry 3 measurements and average (in micrometers)
4. Comar et al. [15]	Sprite Zero pH 2.6	7 days: 30 mL Sprite Zero 4x/day 90s. Dentifrice treatment: immersion in 0.5 mL of the slurry for 15s after the first and last erosive challenge. Abrasion: during the 15s seconds of immersion in the slurry. Load 1.5N. Storage in artificial saliva pH 6.8 2h between cycles and overnight after the last cycle.	Contact profilometry 4 measurements and average (in micrometers)
5. Ganss et al. [16]	Citric acid pH 2.5	10 days: 250 mL citric acid 6 x/day 2 min. 10 mL of the slurry 2 min. Abrasive brushing 15s during the 2 min immersion in the slurry after the first and last erosive cycle of the day. Load 200 g, 150 oscillations/min. 1 hr interval between cycles in remineralizing solution pH 6.7.	Optical profilometry 3 lines with intervals of 0.2mm and 2mm in length, regression lines 0.5mm in length, tissue loss value referring to the average of the 3 lines in micrometers
6. Moron et al. [17]	Sprite Zero pH 2.6	7 days: 30 mL Sprite Zero 4x/day 90s. Dentifrice and abrasion treatment: brushing 15s after the first and last erosive challenge of the day. 166 oscillations/s, load 1.5 N. Storage in artificial saliva pH 6.8 2h between cycles and overnight after the last cycle.	Contact profilometry 4 measurements and average (in micrometers)
7. Ganss et al. [18]	Citric acid pH 2.5	10 days: 250 mL citric acid 6x/day 2 min. Dentifrice treatment: slurry for 2 min. Abrasion: for 15s in the 2 min immersion in slurry after the first and last erosive challenge of the day. Load 200 g. 1h interval between cycles in remineralizing solution pH 6.7.	Optical profilometry 3 lines with intervals of 0.2 mm and 2 mm in length, regression lines 0.5 mm long, tissue loss value (in micrometers) referring to the average of the vertical distance between the regression lines of the 3 lines
8. Mosquim et al. [19]	Citric acid pH 2.5	7 days: citric acid 4x/day 90s. After the first and last erosive challenge day 15s abrasive brushing with the slurry, load 1.5 N. Storage in artificial saliva pH 6.8 2h between cycles.	Contact profilometry 5 measurements $5mm^2$ at the beginning and after the experiment, at the end the measurements were compared and the depth in micrometers was calculated

Table II - Continued...

	Erosive agent	Erosive-abrasive cycle	Surface Loss Assessment Method
9. Soares et al. [20]	Cola drink pH 2.6	5 days: 30 mL cola drink 4x/day 5 min. Immediately after erosive challenge or after 30 min: immersion in slurry and abrasion 60s. 280 strokes/min, load 100 g. 1h in 6.8 pH artificial saliva between each cycle.	Contact profilometry 5 measurements and average (in micrometers)
10. Wegehaupt et al. [21]	Hydrochloric acid pH 2.6	21 days: immersion in 20 mL slurry 100s and abrasive brushing 20s (20 strokes, load 2.5 N). Storage in artificial saliva pH 1h. 2 mL HCL 2 min 9 times/day. 1h after last erosive challenge: immersion in 20 mL slurry 100s and abrasive brushing 20s (20 strokes, load 2.5 N).	Contact profilometry 5 repeated lines at 7, 14, and 21 days. The surface loss was calculated in micrometers by overlapping the traces, with reference to those made at the beginning
11. Simões et al. [22]	Citric acid pH 2.5	3 days: 30 mL citric acid 3x/day 90s. Treatment: abrasive brushing with the slurry 15s (load 1.5 N). 2h in artificial saliva pH 6.8 between erosive challenges and overnight.	Contact profilometry 5 measurements 5mm^2 at the beginning and after the experiment, at the end the measurements were compared and the depth in micrometers was calculated
12. Passos et al. [23]	Concentrate Orange juice pH 3.38	5 days: concentrated orange juice 3x/day 2 min. Artificial saliva 60s. Abrasion: brushing on slurry 150 strokes (200 g load, 4.5 movements).	Contact profilometry 4 measurements and average (in micrometers)

Table III - Description of studies data about tested toothpastes and surface loss values. (n=12)

	Tested toothpastes	Surface loss
1. Moretto et al. [8]	1. Placebo (without fluoride) pH 8 2. 1100 µg F/g pH 8 3. 500 µg F/g + TMP pH 6.97 4. 5000 µg F/g pH 7.75	1. 4.63µm ± 0.54 2. 3.43µm ± 0.38 3. 2.28µm ± 0.26 4. 2.18µm ± 0.30
2. Ganss et al. [13]	1. Theramed Natural White 1450 ppm F NaF pH 7.1 2. Perlodent Kraeuter 1450 ppm F NaF pH 8.1 3. Theramed 2in1 Original 1450 ppm F NaF pH 7.3 4.Odol Med 3 Pro Clean 1400 ppm F NaF pH 7.1 5. Blend-A-Med Classic 1450 ppm F NaF pH 6.3 6. Sensodyne MultiCare 1400 ppm F NaF pH 6.0 7. GUM Original White 1490 ppm F NaF pH 7.2 8. Dentagard Original 1450 ppm F NaF pH 7.0 9. Pronamel KN03, 1450 ppm F NaF pH 7.0 10. ApaCare 1450 ppm F NaF, 1% hydroxyapatite nanoparticles pH 6.7 11. BioRepair zinc carbonate and hydroxyapatite, fluoride-free pH 7.8 12. Chitodent chitosan, fluoride-free pH 6.3 13. ProExpert Gum Protection 1450 ppm F: 1100 SnF2, 350 NaF; 3436 ppm Sn SnF2 pH 6.0 Control toothpaste Aronal fluoride-freebrand without fluoride pH 7.5	1. 25.5 µm ± 3.2 2. 17.5 µm ± 4.7 3. 17.2 µm ± 2.8 4. 20.6 µm ± 4.7 5. 20.1 µm ± 4.1 6. 22.1 µm ± 4.3 7. 17.6 µm ± 5.0 8. 22.3 µm ± 5.8 9. 15.7 µm ± 3.2 10. 22.1 µm ± 3.6 11. 28.9 µm ± 5.2 12. 20.7 µm ± 4.3 13. 19.2 µm ± 9.2 14. 6.3 µm ± 2.1 Control group Negative control – erosion and abrasion with Aronal without fluoride: 24.8 µm ± 3.4
3. Rochel et al. [14]	1. Placebo 2. 10% xylitol 3. 10% xylitol + 1030 ppm F (NaF) 4. 1030 ppm F (NaF)	1. 7.3 µm ± 0.9 2. 4.9 µm ± 1.2 3. 3.9 µm ± 1.1 4. 4.6 µm ± 0.8

Table III - Continued...

	Tested toothpastes	Surface loss
4. Comar et al. [15]	1. Placebo (without fluoride) pH 5.6 2. Experimental NaF 1450 ppm F pH pH 6.0 3. Experimental TiF4 1450 ppm F pH 3.8 4. Experimental SnF2 1450 ppm F pH 3.7 5. Experimental SnF2 (1100 ppm F) + NaF (350 ppm F) pH 3.9 6. Experimental TiF4 (1100 ppmF) + NaF (350ppm F) pH 4.4 7. Pro Health SnF2 (1100 ppm F) + NaF (350 ppm F) pH 5.7 8. Crest NaF 1500 ppm F pH 6.9	1. 5.0 µm ± 0.9 2. 2.9 µm ± 0.7 3. 2.3 µm ± 0.7 4. 2.8 µm ± 1.1 5. 1.7 µm ± 0.7 6. 1.5 µm ± 0.4 7. 2.9 µm ± 1.0 8. 4.1 µm ± 0.9
5. Ganss et al. [16]	1. Experimental 1400 ppm F NaF pH 4.7 2. Experimental 1400 ppm F NaF pH 6.5 3. Dentagard 1450 ppm F NaF pH 7.3 4. ProExpert enamel shield NaF/SnCl2 (1400 ppm F NaF) pH 5.3 5. Meridol AmF/SnF2 (1400 ppm F – 350 AmF, 1050 SnF2; Sn2+ - 3280 SnF2 pH 4.5 6. Experimental AmF/NaF/SnCl2 (1400 ppm F – 700 AmF, 700 NaF; Sn2+ - 3500 SnCl2) pH 4.4 7. Experimental AmF/NaF/SnCl2/chitosan (1400 ppm F – 700 AmF, 700 NaF; Sn2+ - 3500 SnCl2) pH 4.4 8.. Experimental placebo (without fluoride) pH 6.4	1. 16.5 µm ± 3.0 2. 14.0 µm ± 2.7 3. 12.6 µm ± 3.9 4. 14.7 µm ± 5.1 5. 13.5 µm ± 4.8 6. 12.4 µm ± 4.2 7. 6.6 µm ± 3.5 Placebo (negative control): 20.2 µm ± 3.8
6. Moron et al. [17]	Experimentals 1. 550 ppm F NaF pH 4.5 2. 1100 ppm F NaF pH 4.5 3. 5000 ppm F NaF pH 4.5 4. Placebo (without fluoride) pH 4.5 5. 550 ppm F NaF pH 7.0 6. 1100 ppm F NaF pH 7.0 7. 5000 ppm F NaF pH 7.0 8. Placebo (without fluoride) pH 7.1 Comercials 9. Colgate Baby Barney 500 ppm F NaF pH 7.0 10. Crest 1100 ppm F NaF pH 7.0 11. Prevident 5000 ppm F NaF pH 7.0	1. 5.6 µm ± 0.8 2. 5.5 µm ± 0.8 3. 5.5. µm ± 0.9 4. 9.6 µm ± 1.2 5. 6.4 µm ± 0.4 6. 5.5 µm ± 1.2 7. 5.7 µm ± 1.0 8. 9.8 µm ± 1.0 9. 9.3 µm ± 1.0 10. 8.8 µm ± 0.9 11. 9.8 µm ± 0.8
7. Ganss et al. [18]	1. Dentifrice Emofluor 1000 ppm F SnF2 pH 4.6 2. Elmex Erosion Protection 1400ppm F AmF e NaF, SnCl2 pH 4.0 3. Oral-B ProExpert Enamel Shield 1450ppm F NaF e SnCl2 pH 6.2 4. Chitodent chisotan pH 6.3 5. Biorepair hydroxyapatite pH 8.7 6. ApaCare 1450ppm F NaF and hydroxyapatite pH 7.4 7. ActiSchmelz NaF and hydroxyapatite pH 8.2 8. Sensodyne Pronamel 1450 ppm F NaF pH 7.8 9. Sensodyne Multicare 1450 ppm F NaF pH 7.7 10. Elmex Sensitive 1400 ppm F AmF pH 4.8 11. Theramed Natural White 1450 ppm F NaF pH 7.5 12. Theramed ProElectric 1450 ppm F NaF pH 7.6 13. Theramed Original 2in1 1450 ppm F NaF pH 7.7 14. Theramed Interdental 1450 ppm F NaF pH 7.3 15. Pearls&Dents 1200ppm F AmF e NaF pH 6.0	1. 5.4 µm ± 2.3 2. 9.0 µm ± 2.7 3. 8.5 µm ± 1.4 4. 12.8 µm ± 4.3 5. 13.4 µm ± 3.3 6. 7.6 µm ± 2.6 7. 14.1 µm ± 2.0 8. 7.9 µm ± 2.1 9. 12.4 µm ± 2.1 10. 10.2 µm ± 1.9 11. 13.6 µm ± 4.9 12. 12.2 µm ± 2.9 13. 12.4 µm ± 3.3 14. 22.5 µm ± 4.4 15. 14.6 µm ± 1.6
8. Mosquim et al. [17]	1. Oral B 3D White 1450ppm F NaF 2. Close up Diamond Attraction Power White 1450ppm F NaF 3. Sorriso Xtreme White 4D 1450ppm F NaF 4. Colgate Luminous White 1100ppm F NaF 5. Crest Convencional 1500ppm F NaF	1. 3.68 µm ± 1.06 2. 1.51 µm ± 0.95 3. 3.17 µm ± 0.80 4. 3.44 µm ± 1.29 5. 2.35 µm ± 1.44

Table III - Continued...

	Tested toothpastes	Surface loss
9. Soares et al. [20]	1. Sensodyne Pronamel Potassium nitrate 5%, 1425ppm F NaF pH 7.0 2. Crest Cavity Protection 1100ppm F NaF pH 7.0 3. Sensodyne Original Strontium chloride 10% and calcium carbonate, without fluoride pH 7.4	Erosion+Abrasion 1. 7.25 μm ± 0.76 2. 7.24 μm ± 0.88 Control group: 3. Sensodyne Original: 10.40 μm ± 1.13 Erosion+30'+Abrasion 1. 6.61 μm ± 0.83 2. 5.84 μm ± 0.90 Control group: 3. Sensodyne Original: 7.45 μm ± 1.87
10. Wegehaupt et al. [21]	1. Elmex Erosion Protection	1. 7 days – 0.32 μm ± 0.26 14 days – 0.50 μm ± 0.65 21 days – 0.81 μm ± 0.80 Control group (no toothpaste) 7 days – 2.36 μm ± 0.35 14 days – 4.47 μm ± 0.89 21 days – 6.63 μm ± 1.46
11. Simões et al. [22]	1. Crest Anti-cavity regular 1500 NaF	1. 1.32 μm (1.25-146)
	2. Crest 3D White 1500 NaF	2. 1.11 μm (1.00-1.38)
	3. Colgate Total 12 Clean Mint 1450 NaF	3. 1.31 μm (1.28-1.45)
	4. Colgate Optic White 1300 Monofluorphosphate of sodium	4. 1.08 μm (1.04-1.14)
	5. Placebo (without fluoride)	5. 2.28 μm (2.18-2.39)
12. Passos et al. [23]	1. Toothpaste without fluoride	1. 3.62 μm ± 2.06
	2. 1100 ppm F NaF	2. 1.88 μm ± 0.71

fluoride, only two showed less surface loss than the negative control (erosion only), while the others containing similar fluoride concentration increased the surface loss. The tin toothpastes resulted in lower surface losses when compared to the negative control. Regarding the abrasive particles, their size had no impact, while their quantity was relevant.

In the study by Soares et al. [20], the association of potassium nitrate with sodium fluoride was not more effective when compared to conventional fluoride toothpaste with only sodium fluoride. When compared to non-fluoride toothpaste (*Sensodyne Original*), used as a control, *Crest Cavity Protection* (1100ppm F NaF) reduced tissue loss by an average of 25.8% and *Sensodyne Proenamel* (potassium nitrate and 1425 ppm F NaF) by 20.5% [20].

The study by Passos et al. [23] tested the effect of two toothpastes for kids, one non-fluoridated and one fluoridated (1100 ppmF NaF) in erosive-abrasive cycles in deciduous teeth. The two dentifrices presented similar results to the control group (abrasion with distilled water), but they were significantly different from each other, with the fluoride dentifrice showing less loss of enamel surface.

Mosquim et al. [19] tested fluoride whitening toothpastes containing hydrated silica as an abrasive agent. Three of the four whitening toothpastes under test contained pyrophosphate in their composition, and the whitening toothpaste that showed the least loss of enamel surface was the only one without pyrophosphate in its composition. Similarly to hydrated silica, pyrophosphate is also an abrasive agent [29]. The whitening toothpaste without pyrophosphate in its composition showed similar surface loss when compared to the conventional fluoride toothpaste tested.

It demonstrates that the association of silica and pyrophosphate abrasive agents can lead to greater surface loss since the concentration of all tested toothpastes was similar, varying between 1100 and 1500 ppm F [19]. Thus, whitening dentifrices, due to their greater abrasiveness, should not be indicated for patients at risk of erosive tooth wear, emphasizing the importance of adequate dentifrice prescription for different patient profiles. On the other side, the study by Simões et al. [22] analyzed conventional and whitening toothpastes. The authors concluded that whitening dentifrices did not increase erosive tooth wear when compared to conventional toothpastes. Unlike the study by Mosquim et al. [19].

DISCUSSION

Systematic literature reviews are designed to answer a specific question about a problem through a rigorous synthesis, outlined by a protocol. The literature review helps the researcher to identify gaps, consensus and controversies regarding a research object [24].

Tooth tissue loss and surface hardness can be assessed by (optical and contact) profilometry [25]. This method has its limitations, such as the possibility of creating scratches on the softened surface of tooth enamel [19]. However, it is a widely used method because it can assess early and advanced losses [20], so it was chosen as an inclusion criterion for this review.

The erosion and abrasion protocol were selected for it resembles the clinical reality more closely, since the toothpaste is applied through tooth brushing [26]. When studies that analyzed only the application of slurry toothpaste and the studies in which slurry application was associated with brushing were compared, it was observed that samples abrasion led to the greatest loss of enamel surface in experimental groups [8,13,14,18,20,21,27].

Rochel et al. [14] concluded that the addition of 10% xylitol to 1030 ppm F (NaF) fluoride toothpaste increases its protective effect, while NaF only toothpastes and 10% xylitol only toothpastes showed similar surface losses. The results of the association between NaF toothpaste and 10% xylitol cannot be related to the action mechanism of this added substance, as the toothpaste containing only 10% xylitol showed inferior and similar results to the toothpaste containing only NaF. Therefore, the effect of xylitol may be linked to the abrasive procedure, acting as a lubricant and reducing the impact of brushing eroded enamel [14].

Moron et al. [17] evaluated the effect of experimental and commercial dentifrices with acidic and neutral pH in different fluoride concentrations. Liquid (experimental) toothpastes, regardless of their pH, similarly reduced enamel wear when compared to placebo (no fluoride) and commercial groups. Based on the study by Buzalaf et al. [28], the authors point out that it is possible to speculate that liquid (experimental) toothpastes allow greater formation of a calcium fluoride layer when compared to commercial toothpastes [17]. Unlike Moretto et al. [8] who demonstrated a greater preventive effect of the experimental toothpaste with a concentration of 5000ppm F when compared to that of 1000ppm F, Moron et al. [17] did not find this difference between experimental toothpastes with the same fluoride concentration, which may be related to the liquid consistency of the toothpastes.

Wegehaupt et al. [21] compared the toothpaste Elmex Erosion Protection, a new gel system, and a fluoride-free toothpaste. The new products tested showed no reduction in surface loss, while the Elmex toothpaste significantly reduced the loss of enamel surface when compared to the control group (erosion and abrasion without toothpaste). The protection offered by this toothpaste may be related to the incorporation of tin into the dental structure, as well as fluoride, forming a shield against acid attacks [9,30]. However, it is important to emphasize that this study did not use a placebo or conventional toothpaste for control, thus making it difficult to compare the real preventive effect of this toothpaste, which has already been pointed out in other studies as having a good anti-erosion effect.

Similarly, in the study by Moretto et al. [8], the use of fluoride toothpaste containing sodium fluoride showed a reduction in surface loss when compared to toothpastes without fluoride. This is probably due to the calcium fluoride layer formed on the enamel, which partially reduced wear in the erosion and abrasion cycles [23]. The fact that both toothpastes did not present significant differences when compared to the control group was not an expected result, and the authors relate this to the fact that children's toothpastes have lower abrasiveness and their pH is similar to that of water [23].

Besides human permanent teeth, some studies used bovine teeth as samples. It is acceptable given that the enamel surface loss was evaluated in comparison to a control group [31]. One study carried out experiments with deciduous enamel. Deciduous enamel is less mineralized and erosion progression occurs faster if compared to permanent tooth enamel [32]. This fact highlights the importance of early diagnosis of erosive tooth wear in primary dentition and the correct indication of low-abrasive fluoride toothpastes.

Exposure to acids in erosive challenges varied in duration, days and cycles, which makes it difficult to compare different studies. Soft drinks, concentrated orange juice, and citric and hydrochloric acids were used as erosive agents. Regarding the abrasive challenges, in addition to different loads, they varied in terms of time of application.

Of the twelve studies included in this review, eight used non-fluoride placebo toothpastes (experimental or commercial) as controls. The other studies [17,18,21,23] did not use toothpastes as a control group. However, all tested conventional fluoride toothpastes or non-fluoride toothpastes in the groups and that could allow some comparison, except for Wegehaupt et al. [21]. These divergences, along with the different protocols in the erosion and abrasion cycles, make it difficult to compare the studies results.

As to fluorides and their association with different active ingredients, the studies by Moretto et al. [8] and Rochel et al. [14] demonstrate that the association of different active ingredients to dentifrices with low concentration of sodium fluoride may be promising to prevent erosive tooth wear. Moreover, the results found by Comar et al. [15] demonstrate that the association of conventional fluorides with metallic ones is also promising. The study by Ganss et al. [16] demonstrated that the association of chitosan with tin ion and conventional fluorides forms layers of each active ingredient and together these layers bring better results in preventing erosive tooth wear.

Wegehaupt et al. [21] and Ganss et al. [18] tested the same toothpaste (*Elmex Erosion Protection*) and concluded that it reduced surface loss compared to the control group. It is important to emphasize that in both studies, the erosion and abrasion protocols, as well as the control group, were different and showed promising results for the same toothpaste. By analyzing the composition of the toothpaste, it is possible to think that the incorporation of tin, as well as that of fluoride, forms a shield against acid attacks [9,30]. Still, in Ganss et al. [18], *Elmex Erosion Protection* was not as efficient as *Emofluor TP* (tin fluoride) or as *ApaCare* (sodium fluoride and hydroxyapatite), which presented similar results to the positive control (gel without abrasive particles).

Formula differences in toothpastes containing the same concentration of the same active ingredient (sodium fluoride) showed divergent results, e.g., Moretto et al. [8] and Moron et al. [17], which draws attention to the implications of changing toothpaste consistency.

In the study by Simões et al. [22], the toothpaste that showed less surface loss had pyrophosphate abrasive in its composition, which in Mosquim et al. [19], was the agent responsible for greater enamel surface loss, and also MFP as fluoride. Sodium monofluorophosphate requires enzymatic degradation to release fluorine ions, and the slurry preparation in the study does not have enzymes for MFP degradation. Also, several characteristics of dentifrices are related to the prevention or not of erosive tooth wear. The effects of active ingredients present in dentifrices are interdependent on other chemical and physical characteristics they have [33]. Chemical and physical impact on enamel is difficult to interpret as toothpastes composition is complex [13].

CONCLUSION

The studies evaluated a large number of fluoride composites regarding surface loss in enamel samples submitted to erosion and abrasion protocols. Conventional fluoride toothpastes (NaF) presented similar results compared to anti-erosion formulations. The selected articles presented different erosion and abrasion protocols, making it difficult to compare them, given that different protocols can result in less or greater loss of enamel surface. In addition, different commercial and experimental toothpastes with active ingredients and varied indications were tested. The results must be interpreted carefully due to methodological differences and also because toothpastes have complex formulas that are related to their performance. Other properties of dentifrices need to be investigated to clarify the effects of dentifrices on erosive tooth wear.

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Author's Contributions

SCN: Data collection, data analysis and interpretation, drafted manuscript, critically revised manuscript. LCR: Data analysis and interpretation, critically revised manuscript. PSS: Data analysis and interpretation, critically revised manuscript. SMA: Contributed to conception and design, critically revised manuscript. FMF: Contributed to conception and design, critically revised manuscript. CMA: Contributed to conception and design, data collection, data analysis and interpretation, drafted manuscript, critically revised manuscript.

Conflict of Interest

The authors have no conflicts of interest.

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Regulatory Statement

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