Efficacy of Three Remineralizing Agents on Erosion of Root Dentin by Cola Drink: An In Vitro Study

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Abstract

Objective The aim of the study was to investigate the effects of silver diamine fluoride (38% SDF), sodium fluoride (NaF) varnish, and casein phosphopeptide-amorphous calcium phosphate fluoride (CPP-ACPF) on cola-eroded root dentin microhardness and mineral alteration in vitro.

Materials and Methods Forty human root dentin slabs were exposed to alternating 10 cycles of cola drink and artificial saliva, repeated 3 times at 6-hour intervals. Specimens were randomly assigned to four groups: control (deionized water), 38% SDF, NaF varnish, and CPP-ACPF. All specimens underwent the second erosion process. Microhardness was measured at baseline (KHN_0), pretreatment (KHN_1), and posttreatment (KHN_2). The mean difference of microhardness ($KHN_{2\text{-}1}$) was analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc tests ($\alpha = 0.05$). The chemical composition and surface morphology were assessed using energy dispersive spectroscopy (EDS) and scanning electron microscope (SEM).

Results All experimental groups exhibited dentinal tubule occlusion. Both 38% SDF and NaF varnish demonstrated a statistically significant increase in microhardness compared to CPP-ACPF. However, CPP-ACPF was comparable to the control group. EDS analysis showed an increase in weight percentage of fluorine in all groups. Furthermore, silver and chlorine were detected in the 38% SDF group.

Conclusion All treatments enhanced eroded root dentin microhardness, with 38% SDF and NaF varnish demonstrating superior acid resistance and preventing morphological changes induced by cola re-immersion.

Keywords
- dental erosion
- root dentin
- surface hardness
- cola drink
- SDF
- CPP-ACPF
- sodium fluoride varnish

Introduction

Dental erosion is a growing concern as it can cause irreversible damage to dental hard tissues across all age groups. It occurs when the tooth surface is repeatedly exposed to acidic substances over prolonged period.[1] Four main factors contribute to dental erosion: the quality of the tooth structure, buffer capacity in oral cavity, and intrinsic and extrinsic factors of patients.[2] Among these, dietary habits play a crucial role, with acidic foods and beverages being the most common extrinsic factors.[3] Numerous studies have

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highlighted the high potential of carbonated cola drinks, which contain citric acid, maleic acid, and phosphoric acid, to cause dental erosion.[4] These acids decrease the pH of oral cavity and lead to loss of tooth surface.

The aging population, with increased gingival recession and root exposure, faces a higher risk of dentin erosion.[5] Normally, teeth are protected by saliva through the formation of the acquired pellicle, but this defense mechanism has limitations, as repeated acidic exposures can easily remove the protective barrier.[6,7] The primary preventive approach for dental erosion involves reducing the frequency and duration of acid exposure.[8] However, considering the challenge of controlling patients' dietary habits and acid consumption, alternative methods that are less reliant on patient compliance have been proposed for preventing and managing dental erosion.

Researchers have explored various methods to prevent dental erosion, including the use of fluoride containing products in both professional and home applications. These products have been shown to increase dental tissue resistance to acids and enhance tooth hardness, in addition to their role in caries prevention.[9] The remineralization process facilitated by fluoride promotes the formation of less soluble fluorapatite on tooth surface, lowering critical pH value and reducing demineralization from acidic challenge.[10] High fluoride concentrations delivered through oral rinses, gels, and varnishes have been studied for enamel and dentin erosion. In vitro studies demonstrated the effectiveness of 1.23% acidulated phosphate fluoride (APF) gel and 2.26% sodium fluoride (NaF) vanish in hardening enamel demineralized by cola drink,[11] as well as the efficacy of 4% titanium tetrafluoride (TiF_4) varnish and 5.42% NaF varnish in reducing enamel and root dentine erosion.[12]

Among the fluoride containing products, silver diamine fluoride (SDF) has gained attention and has been utilized by clinicians for decades in countries such as Japan, Australia, Brazil, and China.[13] SDF has been proved to inhibit demineralization and promote remineralization.[14,15] Its application is simple, painless, noninvasive, and cost-effective. SDF received Food and Drug Administration (FDA) approval as dentin desensitizing agent in 2014 and have been allowed for off-label use as an interim caries medicament since 2016.[16] However, the published evidence regarding SDF's role in dental erosion management remains limited.[17,18] The utilization of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) is a strategy to control dental erosion as a calcium and phosphate in oral cavity. When combined with fluoride ions, CPP-ACP forms CPP-ACPF (casein phosphopeptide-amorphous calcium phosphate fluoride) in tooth cream, providing additional fluoride, calcium, and phosphate ions for remineralization. Both CPP-ACP and CPP-ACPF have been shown to increase the microhardness of softened enamel, with CPP-ACPF exhibiting greater remineralization potential than CPP-ACP.[19]

However, there is still uncertainly regarding the effectiveness of remineralizing agents in preventing the decrease in surface hardness and morphological changes of tooth structures caused by dental erosion from cola drinks. Therefore, the aim of this study was to compare the efficacy of SDF, NaF varnish, and CPP-ACPF on erosion caused by cola drinks. The null hypothesis was that all remineralizing agents had no effect on microhardness of eroded root dentin.

Materials and Methods

Sample Size Calculation

The sample size was calculated based on data from a previous study.[20] The calculation was performed using G*Power program version 3.1.9.6 (Kiel University, Germany) with an effect size of $f = 0.73$, power $1-\beta = 0.8$, and $\alpha = 0.05$. The sample size was determined as 10 specimens per group accounting for experimental errors. Thus, the total sample size for this study consisted of 40 specimens.

Specimen Collection

The study protocol was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU-2022-031). Sound human premolars and third molars extracted for orthodontic reason were collected from patients aged 18 to 30 years. The teeth were stored in 0.1% thymol solution pH 7.0 (M DENT, Mahidol university, Bangkok, Thailand) at 4°C up to 2 months after extraction for disinfection. The teeth were examined under a stereomicroscope (SZ 61, Olympus, Tokyo, Japan) at 40X magnification for surface damage, cracks, or defects. Teeth with carious lesions, moderate to severe noncarious cervical lesions, restorations, cracks, or defects were excluded.

Specimen Preparation

Forty root dentin slaps measuring $5 \times 5\ \text{mm}^2$ were prepared from the mesial or distal aspect of the root using a low-speed cutting machine (IsoMet 1000, Buchler Ltd., Illinois, United States). The upper border of the root dentin slabs was at the cementoenamel junction (CEJ) level. The thickness of root dentin slabs was at least 1.5 mm from the root canal wall to the external surface. The root dentin slabs were embedded in epoxy resin in silicone mold ($2 \times 2 \times 1\ \text{mm}^3$). The embedded surfaces were polished with 600, 1,000, 1,200, and 2,000 grit silicon carbide grinding papers (Carbimet, Buchler Ltd.) and gloss polished with aluminum oxide powder by using a polishing machine (Minitech 233, PRESI, Grenoble, France) to create a flat and smooth surface. Surface debris was removed using ultrasonic device with deionized water (Ultrasonic cleanser 5210, HEIDOLPH, Germany) for 5 minutes. The polished specimens were stored in an incubator at 37°C with 100% relative humidity until use.

Microhardness Measurement

Knoop microhardness measurements were performed using a microhardness tester (FM810, Future-Tech Corp., Kanagawa, Japan) with a 25-g force applied for 10 seconds. Five indentations were made, spaced 0.5 mm apart from each. The mean hardness value for each specimen was calculated from averaging the value of all five indentations. Baseline microhardness test (KHN_0) was conducted at a location 1 mm from the left border and 0.75 mm from the upper border.

Specimens included in the study were selected based on an initial mean surface microhardness of 60 to 80 KHN. Specimens were randomly divided into four groups, 10 specimens per each group using systematic sampling method. After the first erosion process, pretreatment microhardness test (KHN_1) was performed at a location of 2.5 mm from the left border and 0.5 mm from the upper border. The KHN_0 and KHN_1 were initially measured to ensure that there were no significant differences in microhardness data between groups. The posttreatment microhardness test (KHN_2) took place after the second erosion process at a location 3.5 mm from the left border and 0.75 mm from the upper border. The mean difference of surface microhardness was calculated by $KHN_{2\text{-}1} = KHN_2 – KHN_1$ for comparison among experimental groups.

Erosion Process by Cola Soft Drink

The specimens' surface (area size $2 \times 5\,mm^2$) from the left border that had undergone baseline microhardness testing was coated with three layers of acid-resistant nail varnish (Revlon Professional, New York, United States). The protocol of erosion process followed previous studies.[21,22] The erosion process involved immersion in cola three times at 6-hour intervals to simulate three mealtimes. Remineralization in artificial saliva occurred between erosive processes to mimic pH changes in the oral environment. The cola drink (Coca-Cola, ThaiNamthip, Bangkok) was opened just before experiment. The pH of the cola drink and artificial saliva was measured using a pH meter (Orion Model 420A, ATI Orion Research Inc., Boston, United States). The specimens were then immersed in 32.5 mL of the cola drink for 5 seconds, followed by 32.5 mL of artificial saliva for another 5 seconds. This immersion process was repeated for 10 cycles at room temperature (25°C). The protocol was repeated three times at 6-hour intervals, with the cola drink being replaced each time. During each interval, the specimens were stored in artificial saliva at 37°C. After the immersion process, the specimens were washed with deionized water for 30 seconds. They were then stored in an incubator at 37°C with 100% relative humidity until pretreatment microhardness measurement.

Experimental Treatment (Remineralization Process)

The materials used in the study described in ►**Table 1**. All specimens were assigned to receive different treatments: the control group (immersion in deionized water of 32.5 mL for a minute), the 38% SDF group (Topamine, Dental Life Australia, Samutprakarn, Thailand), the NaF varnish group (Duraphat, Colgate-Palmolive Ltd., Guildford, UK), and the CPP-ACPF group (GC Tooth Mousse Plus, GC Corporation, Tokyo, Japan). Each treatment involved the application of 0.01 g of agents using microbrushes. All remineralizing agents were rubbed on the eroded specimen for 1 minute and the excess were removed with another microbrush. Then, the specimens were left for 3 minutes.

The specimens were stored in artificial saliva at 37°C for 6 hours. After the remineralization process, the specimens were washed with deionized water for 30 seconds and dried by blotting. After the experimental treatment, a re-immersion in cola drinks with the second erosion process was conducted in a single cycle.

Scanning Electron Microscopy and Energy Dispersive Spectroscopy Analysis

Four specimens for each group were randomly selected for chemical composition and surface morphology examination using energy dispersive spectroscopy (EDS) analysis. The pointed EDS analysis was performed using scanning electron microscopy (SEM; Hitachi SU3500, Hitachi Corp., Tokyo, Japan) on the baseline microhardness area and after the second erosion process. The analysis quantified the element calcium (Ca), fluorine (F), phosphorus (P), silver (Ag), and chlorine (Cl) in root dentin specimens. The specimens were mounted on an aluminum stub and coated with gold/palladium powder. Surface morphology was evaluated at magnifications of 1,000X and 10,000X under high vacuum mode at an acceleration voltage of 10 kV.

Statistical Analysis

All data were analyzed using a statistical analysis software (SPSS version 29.0, IBM, New York, United States). The level of statistical significance for all tests is $\alpha = 0.05$. The normal distribution was tested by a Shapiro–Wilk test. A one-way analysis of variance (ANOVA) was used to examine the differences in the KHN_0 and KHN_1 data among groups before analyzing $KHN_{2\text{-}1}$.

The mean difference of microhardness data ($KHN_{2\text{-}1}$) was performed. Homogeneity of variance was assessed by Levene's test. One-way ANOVA test with Tukey's post hoc test was used for comparing $KHN_{2\text{-}1}$ between four experimental groups (control, 38% SDF, NaF varnish, and CPP-ACPF). The characteristics of the mineral compositions will be evaluated by SEM and energy dispersive X-ray (EDX) analysis.

Results

Microhardness Measurement

The baseline microhardness values (KHN_0) ranged from 60.76 to 78.75 KHN, with an average of 63.74 KHN. The statistical analysis of KHN_0 and KHN_1 showed no statistical difference among groups ($p = 0.735$ and 0.472). Posttreatment microhardness values (KHN_2) showed increase compared to pretreatment microhardness values (KHN_1) in all groups (►**Table 2** and ►**Fig. 1**). The mean difference values between pre- and post-treatment ($KHN_{2\text{-}1}$) were 1.84 ± 4.33, 13.28 ± 4.57, 11.87 ± 5.98, and 4.47 ± 4.63 KHN in the control, 38% SDF, NaF varnish, and CPP-ACPF groups, respectively (►**Table 2**). The 38% SDF and fluoride varnish groups exhibited significantly greater increases in $KHN_{2\text{-}1}$ compared to the control group ($p < 0.001$ and <0.001, respectively) and the CPP-ACPF group ($p = 0.002$ and 0.01, respectively). However, there was no significant difference between the 38% SDF and fluoride varnish groups ($p = 0.918$). Similarly, no significant difference was observed between the CPP-ACPF and control groups ($p = 0.633$).

Table 1 Materials used in the study

Material	Manufacturer	Composition	Batch no.
38% SDF (Topamine)	DentaLife Australia, Samutprakarn, Thailand	$Ag(NH_3)_2F$, silver ion (soluble) and water[a] (fluoride = 44,800 ppm)	B0988.1
5% sodium fluoride varnish (Duraphat)	Colgate-Palmolive Ltd, Guildford, UK	Colophonium, ethanol, sodium fluoride, saccharin, isoamyl acetate and water[a] (fluoride = 22,600 ppm)	238345
CPP-ACPF (GC Tooth Mousse Plus)	GC corporation, Tokyo, Japan	Glycerol, CPP-ACP, sodium fluoride, D-sorbitol, sodium carboxyl methyl cellulose (CMC-Na), propylene glycol, silicon dioxide, titanium dioxide, xylitol, phosphoric acid, ethyl propyl butyl p-hydroxybenzoate, flavoring and pure water[a] (fluoride = 900 ppm)	2105241
Cola soft drink (Coca-Cola)	ThaiNamthip, Bangkok, Thailand	Carbonated water, sucrose, phosphoric acid, coloring, and flavoring[a]	N/A
Artificial saliva	Pharmacology Center, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand	Potassium chloride 0.75 g, magnesium chloride 0.07 g, calcium chloride 0.199 g, dipotassium hydrogen phosphate 0.965 g, potassium dihydrogen phosphate 0.439 g, sodium carboxymethylcellulose 6 g, sorbitol 70% 36 g, deionized water up to 1,200 mL[a]	N/A

Abbreviation: CPP-ACPF, casein phosphopeptide-amorphous calcium phosphate fluoride; SDF, silver diamine fluoride.
[a] The manufacturers provided their products' information.

Table 2 The mean Knoop microhardness and *p*-value between groups of KHN_0, KHN_1, KHN_2, and $KHN_{2\text{-}1}$

Treatment	Group (mean KHN ± SD)				*p*-value between groups
	Control	38% SDF	NaF varnish	CPP-ACPF	
Baseline (KHN_0)	68.56 ± 4.69	67.32 ± 4.01	69.06 ± 6.16	70.02 ± 6.51	0.735
Pretreatment (KHN_1)	62.01 ± 5.05	59.72 ± 5.01	61.07 ± 6.34	64.20 ± 8.26	0.472
Posttreatment (KHN_2)	63.85 ± 7.44	72.99 ± 4.87	72.94 ± 6.79	68.67 ± 6.58	0.009
$KHN_{2\text{-}1}$	1.84 ± 4.33	13.28 ± 4.57	11.87 ± 5.98	4.47 ± 4.63	< 0.001

Abbreviation: CPP-ACPF, casein phosphopeptide-amorphous calcium phosphate fluoride; KHN, Knoop hardness number; NaF, sodium fluoride; SD, standard deviation; SDF, silver diamine fluoride.

Scanning Electron Microscopy and Energy Dispersive Spectroscopy Analysis

The EDS analysis revealed a slight change in the weight percentage (wt%) of calcium (Ca) and phosphate (P) across all experimental groups (►**Fig. 2** and ►**Table 3**). The control group is shown in ►**Fig. 2a**. The 38% SDF group (►**Fig. 2b**) exhibited a noticeable increase in weight percentage of fluorine (F), while fluoride varnish (►**Fig. 2c**) and CPP-ACPF groups (►**Fig. 2d**) showed a slight increase. Additionally, an increase in the weight percentage of silver (Ag) and chlorine (Cl) were observed in the 38% SDF group (►**Fig. 2b**).

The SEM images demonstrated that sound root dentin, which was not exposed to acid and remineralizing agents, had numerous dentinal tubules with small irregularities on the tubule walls (►**Fig. 3a, b**). In the control group, dentinal tubules exhibited mineral precipitates (►**Fig. 3c, d**) and rougher surface compared to sound root dentin. In 38% SDF–treated root dentin, globular structures were observed, some of which occluded dentinal tubules and intertubular dentin (►**Fig. 3e, f**). The root dentin surface treated with fluoride varnish showed the presence of irregularly shaped particles aggregated on the surface (►**Fig. 3g, h**). Moreover, both the 38% SDF–treated and fluoride varnish–treated surfaces showed fewer dentinal tubules compared to other treatments. In the CPP-ACPF group, mineral deposits accumulated within the dentinal tubules, and a slight irregularity was observed on the surface of the root dentin (►**Fig. 3i, j**).

Discussion

Root dentin is more susceptible to acid dissolution compared to coronal dentin due to its lower mineral density and dentin hardness.[23,24] The erosive effects of acidic beverages on root dentin can lead to tooth sensitivity, loss of tooth structure, and an increased risk of dental problems. To minimize the erosive impact on exposed root dentin, applying high concentrated fluorides, such as SDF or fluoride varnish, has shown promising but inconclusive results.[17,18] The results

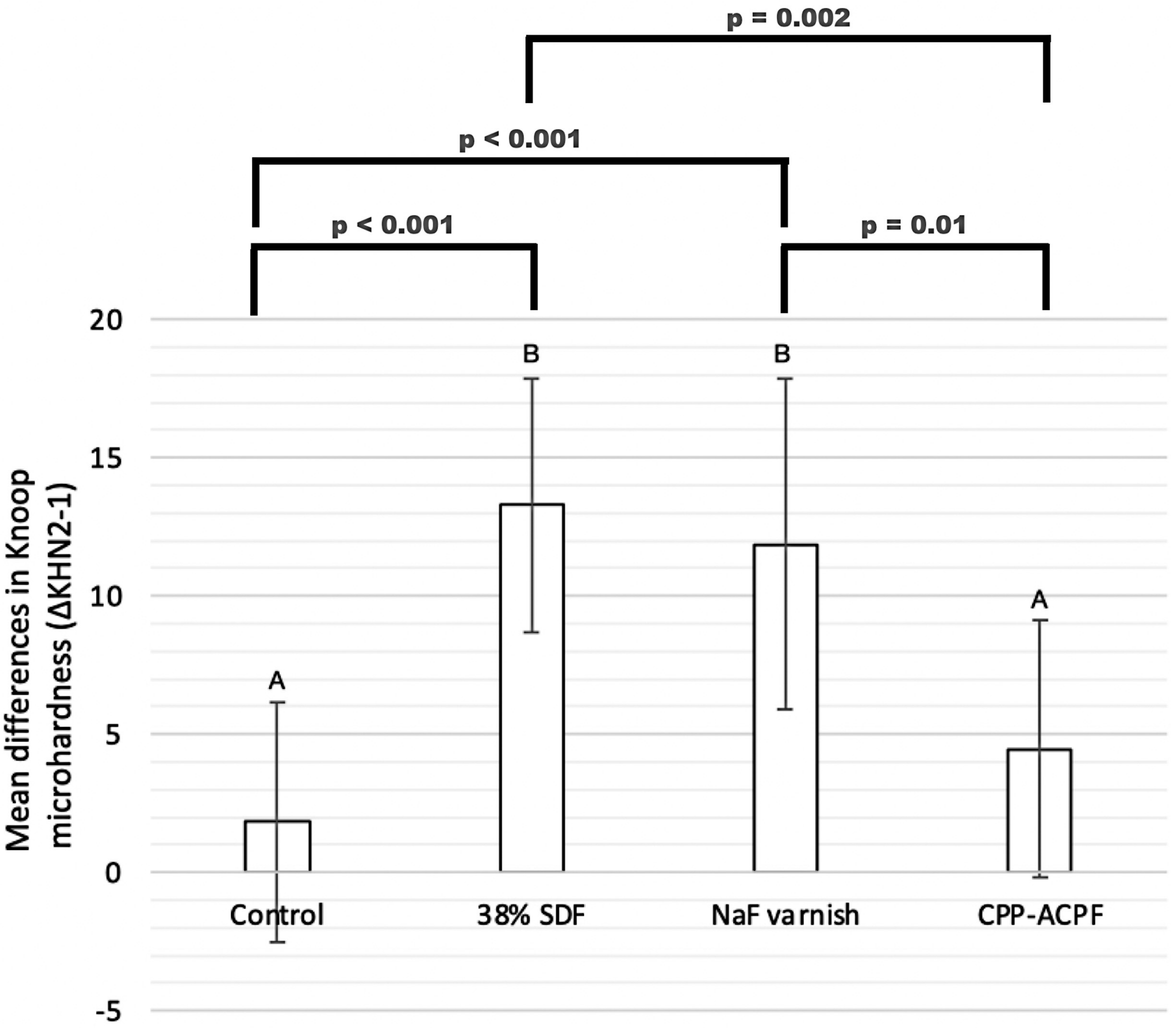

Fig. 1 The mean differences in Knoop microhardness between pre- and posttreatment ($KHN_{2\text{-}1}$). The *relative lines* between bars indicate significant differences ($p < 0.05$). The *vertical bars* indicate standard deviations.

of this study showed that a single application of both 38% SDF and NaF varnish effectively prevented erosion in root dentin, leading to a significant increase in surface microhardness after the cola erosion challenge. Therefore, the null hypothesis was rejected.

Cola soft drink was selected for this study because cola is a hyposaturated solution relative to tooth minerals, and contact with this acidic solution leads to dissolution of tooth structure. The erosive potential of cola on root dentin has been observed, as it can cause demineralization and surface loss. Our study replicated real-life conditions using cyclic specimen immersion in cola, washout with saliva following previous studies,[21,22] and re-immersing the treated root dentin specimens in cola to investigate the acid endurance potential after their initial application.

Fluoride is less effective in preventing erosion compared to prevention of caries due to the lower pH of the acids involved in erosion, unlike bacterial acids.[25] To effectively prevent erosion, the use of highly concentrated fluorides and/or more frequent applications is necessary.[26] NaF varnish (Duraphat) with 22,500 ppm fluoride concentration and 38% SDF (Topamine) claim fluoride levels of 42,442 to 47,257 ppm, reaching 53,394 ppm in a previous study.[27] The high fluoride concentration promotes the formation of a CaF_2-like layer when fluoride ions react with calcium from hydroxyapatite, acting as a physical barrier against acid contact and releasing fluoride ions at low pH.[25,28] However, the CaF_2 layer readily dissolves over time. This emphasized the importance of having adequate density to withstand acid challenges.[29] Fluoride plays a crucial role in preventing surface loss and supporting remineralization by facilitating the formation of fluorapatite and preserving phosphate and calcium ions as a fluoride reservoir.[28,30] Notably, the impact of fluoride ions is more pronounced when comparing the NaF varnish–treated group to the SDF-treated group, with comparable results in surface microhardness testing.

SDF disturbs the caries process and prevents new caries formation simultaneously.[31] The main mechanisms of action in preventing dental erosion are inhibiting demineralization, promoting remineralization, and inhibiting collagen degradation.[32] SDF reacts with hydroxyapatite, forming calcium fluoride (CaF_2) and silver phosphate (Ag_3PO_4), which later

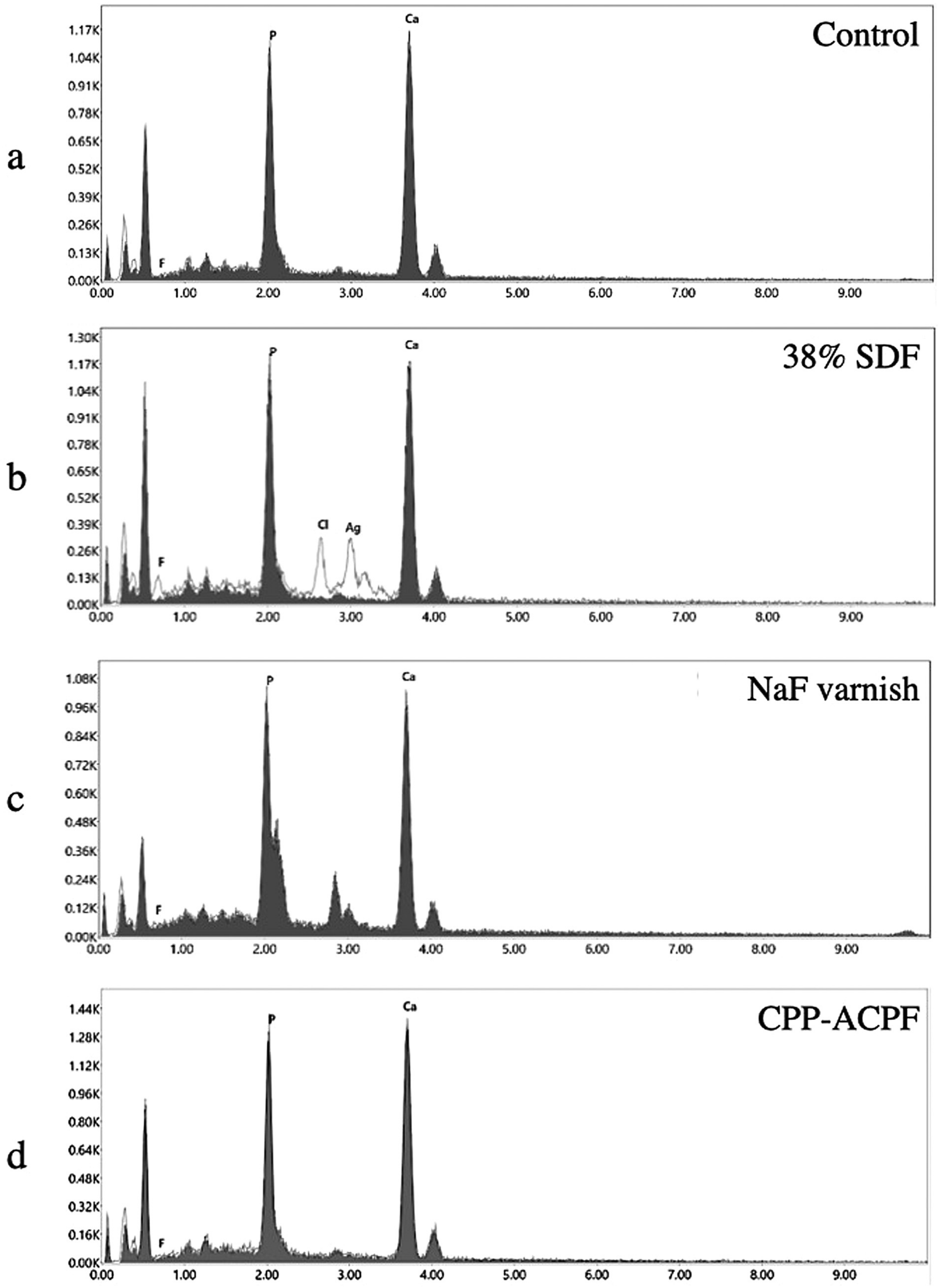

Fig. 2 The energy dispersive spectroscopy (EDS) analysis for four experimental group. (**a**) Control (deionized water), (**b**) 38% SDF (silver diamine fluoride), (**c**) fluoride varnish, and (**d**) CPP-ACPF (casein phosphopeptide-amorphous calcium phosphate fluoride) by comparing between baseline area (*black area*) and treatment area (*black line*).

Table 3 The EDS analysis (wt%) of root dentin surface, displaying the percentage of elements corresponding to the respective surfaces

Treatments	Surface	Ca (%)	P (%)	F (%)	Ag (%)	Cl (%)
Control	Untreated	65.45	28.87	5.69	N/A	N/A
	Treated	64.77	29.05	6.17	N/A	N/A
38% SDF	Untreated	66.44	29.03	2.09	1.98	0.47
	Treated	58.66	25.78	3.70	8.61	3.24
NaF varnish	Untreated	63.16	33.48	3.37	N/A	N/A
	Treated	63.73	32.99	4.02	N/A	N/A
CPP-ACPF	Untreated	65.79	28.86	5.34	N/A	N/A
	Treated	65.47	29.03	5.49	N/A	N/A

Abbreviations: CPP-ACPF, casein phosphopeptide-amorphous calcium phosphate fluoride; EDS, energy dispersive spectroscopy; NaF, sodium fluoride; SDF, silver diamine fluoride; wt%, weight percentage.

form fluorapatite crystals.[33] Fluorapatite formation on the tooth surface decreases the critical pH value and is less soluble than hydroxyapatite.[10] The unstable silver phosphate crystals reduce to silver ions, forming insoluble metallic silver that increases the surface hardness of the affected areas.[34] When chloride ions in saliva react with silver phosphate or silver oxide, silver chloride is formed. Because silver chloride is less soluble than silver phosphate and silver oxide, it may have increased the microhardness of the root dentin treated with SDF. Silver crystals initially form as round nano-sized particles and aggregate over time, forming hexagonal or square-shaped crystals of a sub-micrometer size.[35] However, it is important to consider several limitations, including the potential for staining on demineralized tooth structure.

CPP-ACPF with 900 ppm fluoride concentration (GC tooth mousse plus) could benefit from constant reapplication to enhance effectiveness. Calcium and phosphate ions found in saliva form calcium phosphate precipitation layer, crucial for the remineralization process.[20] The combined use of calcium, phosphate, and fluoride products has a synergistic effect. Fluoride varnish and CPP-ACPF were reported to be able to prevent morphological changes of eroded root dentin and showed that calcium and phosphate increased in the EDS analysis.[36]

In our study, CPP-ACPF showed significant obliteration of dentinal tubules but had low resistance to acid attacks, possibly due to the short-lived nature of calcium phosphate on the tooth surface.[37] On the other hand, NaF varnishes and SDF may be more effective due to their ability to provide prolonged contact to the dental tissues. Considering this, suggesting a more frequent reapplication of CPP-ACPF may serve as an alternative approach for utilizing these materials in patients with acid erosion.[36] Based on our findings, a single application of highly concentrated fluorides may be sufficient to withstand an acid challenge.

EDS and SEM analysis revealed slight changes in calcium, phosphate, and fluorine. Fluorine levels were detected to be higher in the NaF varnish and SDF groups compared to the CPP-ACPF group. This result can be attributed to higher fluoride concentration in NaF varnish and SDF and lower NaF concentration in CPP-ACPF. The SDF-treated group also showed the presence of silver and chlorine, as evidenced by the SEM images (►**Fig. 3e, f**) displaying globular particles of varying sizes on the treated root dentin specimens, which is consistent with the findings of a previous study.[38] In contrast, the NaF varnish–treated specimens (►**Fig. 3g, h**) exhibited irregularly shaped particles identified as CaF_2, which covered the root dentin surface and showed fewer dentinal tubules. These findings provide support for the potential of SDF and NaF varnish in preventing dental erosion.

In this study, we aimed to quantify and characterize root dentin erosion and remineralization effects using a combination of quantitative and qualitative methodologies. Surface microhardness and SEM-EDS were chosen due to their cost-effectiveness and simplicity in assessing initial erosion. However, SEM-EDS has limitations in the depth of analysis, primarily providing information about the top few micrometers of the sample. Therefore, supplementary measurement methods (e.g., microtomography) may be necessary for a more comprehensive analysis.

This in vitro study's limitations include the controlled laboratory conditions, which do not fully represent the complexity of the oral cavity. Our findings imply the potential of remineralizing agents in preventing erosion during a single acid challenge or a short period. Further studies are needed for long-term and repeated acid challenges.

Conclusion

All remineralizing agents used in this study demonstrated efficacy in increasing the microhardness of eroded root dentin. However, only 38% SDF and NaF varnish showed greater acid resistance to prevent morphological changes caused by re-immersed acid in cola.

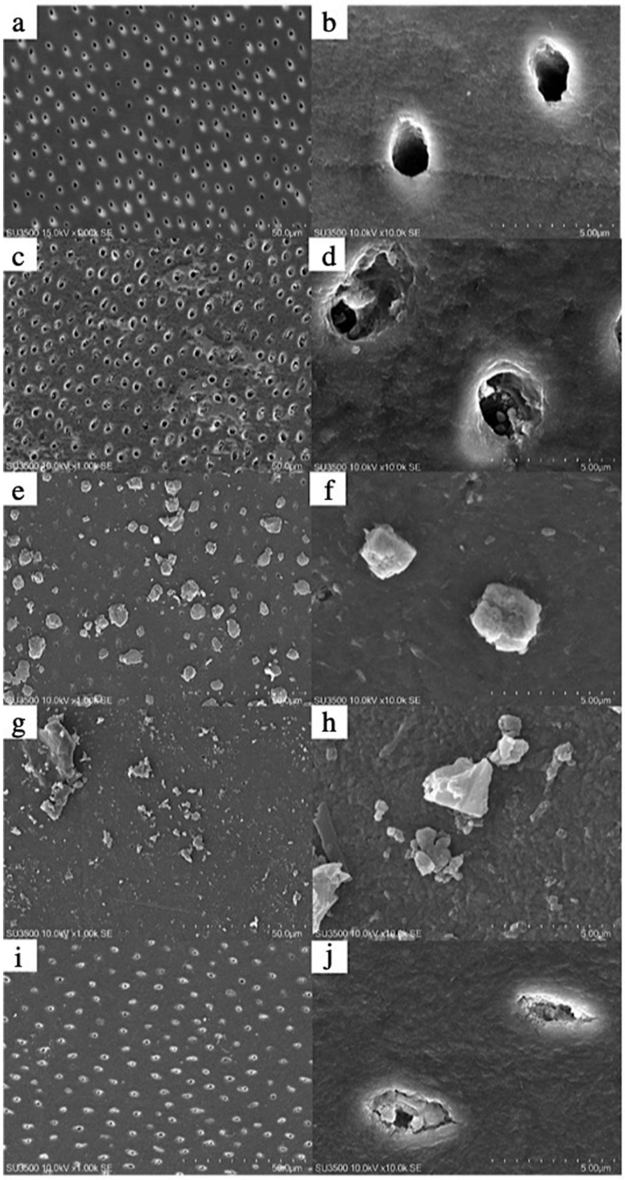

Fig. 3 The scanning electron microscope (SEM) images of surface morphology of the root dentin surfaces. (**a**) 1000x magnification view of sound root dentin. (**b**) 10,000x magnification view of sound root dentin. (**c**) 1,000x magnification view of control group. (**d**) 10,000x magnification view of control group. (**e**) 1,000x magnification view of 38% SDF (silver diamine fluoride) group. (**f**) 10,000x magnification view of 38% SDF group. (**g**) 1,000x magnification view of fluoride varnish group. (**h**) 10,000x magnification view of fluoride varnish group. (**i**) 1,000x magnification view of CPP-ACPF (casein phosphopeptide-amorphous calcium phosphate fluoride) group. (**j**) 10,000x magnification view of CPP-ACPF group.

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Conflict of Interest
None declared.

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