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INFLUENCE OF PRG BARRIER COAT VERSUS SODIUM FLUORIDE VARNISH ON ENAMEL SUBJECTED TO EROSIVE-ABRASIVE CHALLENGE

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ABSTRACT

Objective: To evaluate effect of PRG barrier coat versus NaF varnish and their combined application on microhardness and surface roughness of eroded-abraded enamel during chemo-mechanical cycling.

Material and Methods: 28 human premolars were randomly divided into 4 groups according to preventive treatment (7/group): Group 1, artificial saliva; Group 2, PRG barrier coat; Group 3, NaF varnish; Group 4, NaF varnish + PRG barrier coat. Before treatment, specimens underwent 3 consecutive days of erosion/abrasion challenge (4-erosion "energy drink", 2-abrasion cycles/day), and stored in artificial saliva in-between cycles, overnight. Treatment was applied following grouping, then another 3-day cycle was conducted. Microhardness and surface roughness were assessed at baseline, after first cycling before treatment, after treatment and second cycling. Comparisons between four groups were performed using Kruskal-Wallis test, within each group using Friedman test.

Results: The highest median %change of enamel increase in microhardness and decrease in surface roughness were recorded for Groups 3 and 4, respectively. Group 2 showed the lowest median %change. There was no statistically significant difference between all groups regarding microhardness and surface roughness ($p = 0.119$ and 0.248, respectively).

Conclusions: Irrespective of preventive treatment, microhardness and surface roughness of eroded-abraded enamel did improve after exposure to chemo-mechanical challenge.

KEYWORDS: abrasion, erosion, preventive materials, titratable acidity.

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INTRODUCTION

Consumption of soft, sport and energy drinks is becoming more popular among children and adolescents.[1] Hydrogen ions (H^+) from acidic solutions can replace calcium ions (Ca^{2+}) of the enamel, consequently breaking its crystal structure and initiating dental erosion.[2] The titratable acidity and pH are important indicators for determining erosive potential. This depends on complex interplay of numerous parameters such as acid type, acid concentration, temperature, and duration of the drink held in mouth. The buffering capacity of the saliva can be affected by caffeine present in energy drinks, which reduces salivary flow.[3] Such softening of the enamel surface renders it less resistant, and increases its susceptibility to physical wear such as toothbrush abrasion.[4] Subsequently, erosive tooth wear can lead to severe impairment of esthetics, along with loss of hardness and functionality.[2]

Several efforts are undertaken to elucidate how erosive/abrasive lesions can be prevented. Different methods have been shown to prevent or slow the progression of dental erosion such as the use of topical fluorides.[5] Moreover, highly concentrated fluoride applications, such as oral rinses, gels or varnishes, have been demonstrated to increase abrasion resistance and decrease the development of enamel erosion in vitro and in situ.[4,6,7] The fluoride remineralization process observed in caries is different to erosion as the lesions are diffuse and open to the oral environment. Any remineralization that can occur is restricted to demineralized enamel layer. This data would suggest that sodium fluoride has a role in the protection against dental erosion, particularly when applied after an erosive challenge.[8]

Fluoride has an important protective action on enamel against erosion through precipitation of CaF_2-like material on the eroded dental surface, which is subsequently incorporated into the enamel as hydroxyfluorapatite or fluorapatite, resulting in increased acid resistance to further dissolution. The deposited CaF_2 layer acts as a physical barrier preventing contact of the acid with the underlying enamel, or serves as a mineral reservoir.[5,9]

A revolutionary pre-reacted glass ionomer (PRG) filler, that is prepared by acid-base reaction of fluoroboroaluminosilicate glass with polyalkenoic acid added to resinous materials, has been introduced. This particle is basically an insoluble glass, with a thin external modified layer capable to release ions to the environment. Additionally, S-PRG filler reinforces the varnish creating a stronger and more stable film, in association with higher bonding to tooth structure provided by the bio-adhesive ingredient. S-PRG fillers act in quasi-intelligent way such that their release of fluoride is acidity-dependent. Moreover, strontium released from S-PRG fillers may enhance the acid resistance of teeth by converting hydroxyapatite to strontium-apatite. When compared to fluorapatite, strontium-apatite provides an enhanced acid resistance.[10,11]

Since, erosive tooth wear is dependent on the lifestyle of the patient, then it is important to investigate the preventive treatment modalities facing erosion/abrasion challenges. Therefore, the aim of the present study was to evaluate effect of PRG barrier coat versus NaF varnish and their combined application on microhardness and surface roughness of eroded-abraded enamel during chemo-mechanical cycling.

The first null hypothesis of the current study is that PRG barrier coat will show similar results as NaF varnish, also that the combined application of both protective materials will show similar results to application of the single agent. The second null hypothesis is that roughness and microhardness values after treatment protocols subjected to erosion and abrasion challenges will maintain their baseline values.

MATERIAL AND METHODS

Ethical approval and study experimental design

A total of 28 human premolars, extracted for orthodontic reasons, following the informed consent of the patients, were used in this in-vitro study. The research was performed by relevant guidelines and regulations and all methods were approved by the Research Ethics Committee of the Faculty of Dentistry, Cairo University (approval serial number 181022).

Twenty-eight specimens were randomly divided into 4 groups according to the preventive treatment modalities (7 per group): 1) Artificial saliva (negative control); 2) PRG barrier coat; 3) NaF varnish; and 4) NaF varnish + PRG barrier coat. Microhardness and surface roughness for all groups were analyzed 3 times for all buccal surfaces of the specimens: at baseline and repeated after exposure to first erosion/abrasion challenge, and then re-evaluated after application of the preventive materials under second erosion/abrasion challenge. Energy drink was used as the pro-erosive material. The pH and titratable acidity of the beverage were measured. Based on prior data from Badr and Ibrahim,[12] and by considering mean and standard deviation (SD) values of surface microhardness (SMH) in the different groups primary outcome measure using G power 3.1.9.4 program for sample size based on one-way ANOVA. The study parameters were: two-sided alpha of 0.05, power of 0.95 and means and SD of the groups were 187.4±18.7, 191.9±9, 225.9±1.6. So, the minimum required number was 28 sampling unit (7 teeth per group).

Evaluation of the pH and erosive potential of the energy drink

The energy drink (Red Bull, table 1) pH was evaluated every time using a digital pH meter (Jenway 3505, UK), it was measured directly after the canned beverage was opened. The titratable acidity was evaluated by adding 100 mL of the energy drink in a glass beaker, and 1.046 M sodium hydroxide (NaOH) was gradually added by pipette with constant stirring by a magnetic stirrer (Jenway 1000, UK). Constant monitoring of the pH level was continued until neutralization (pH= 7), and the amount of NaOH needed for reaching neutralization was noted in mL.[13] The pH of the beverage was 2.75, which is below the critical pH of enamel indicating a highly acidic beverage. Moreover, the titratable acidity for each 100 mL of the beverage, 13.2 mL of 1.046 M of NaOH was consumed to reach neutral pH, indicating its highly erosive potential as shown in table 2. This means that the buffering capacity in the oral environment will be compromised, leading to a longer time of acidic pH.

Sample Preparation

All teeth were cleaned from any residual tissue, washed under running tap water and inspected under the stereomicroscope to discard teeth with cracks, restorations, fractures or any developmental defects that could interfere with the results. Teeth were then stored in thymol solution of 0.025% and used within 3 months after extraction. Sectioning of the crown was done in a parallel direction to the occlusal plane 1mm below the CEJ under copious amount of water using Isomet 4000 micro-saw, double-sided, Buehler, USA. Roots were discarded and the teeth were cleaned using pumice water slurry. Specimens were then fixed in self-cured resins, in which each crown was embedded with its buccal surface facing upwards, flushing with the top surface of the block.

Cyclic Erosion/Abrasion Challenge before preventive treatment

All specimens were subjected to 3 consecutive days of erosion/abrasion challenges, applied four times daily, in which each specimen was inserted in a separate container of 17 mL of freshly opened beverage for 10 minutes, then inserted for 50 minutes in artificial saliva (table 1).[14,15] Abrasion cycles were performed in the first and last cycles

TABLE (1) The materials used in the study

Material	Composition	Manufacturer
Red Bull	Water, Sucrose, Glucose, Acid (Citric Acid), Carbon Dioxide, Taurine (0.4%), Acidity Regulators (Sodium Carbonates, Magnesium Carbonates), Caffeine (0.03%), Vitamins (Niacin, Pantothenic Acid, B6, B12), Flavorings, Colors (Plain Caramel, Riboflavin's).	Austria
Artificial saliva	Na_3PO_4 - 3.90 mM $NaCl_2$ - 4.29 mM KCl - 17.98 mM $CaCl_2$ - 1.10 mM $MgCl_2$ - 0.08 mM H_2SO_4 - 0.50 mM $NaHCO_3$ - 3.27 mM, distilled water, and the pH was set at a level of 7.2.[14]	Faculty of Pharmacy, Cairo University, Egypt
PRG barrier coat	Base: S-PRG filler based on Fluoroboroaluminosilicate glass, Distilled water, Methacrylic acid monomer. Activator: Phosphonic acid monomer, Methacrylic acid monomer, Bis-MPEPP, Carboxylic acid monomer, TEGDMA, polymerization initiator.	Shofu, Japan
VOCO Profluorid varnish	Colophony-based varnish containing 5% NaF varnish (22,600 ppm fluoride), Xylitol	VOCO GmbH, Cuxhaven Germany
Sensodyne Original Toothpaste	Purified water, Glycerin, Calcium Carbonate, Strontium Chloride Hexahydrate 10% w/w, Sorbitol, Colloidal anhydrous Silica, Hydroxyethylcellulose, Sodium Methyl Cocoyl Taurate, Aroma, PEG-40 Stearate, Titanium dioxide, Sodium saccharin	GlaxoSmithKline, S.A.E.

per day after erosion, the specimens were then rinsed with distilled water. Electrical toothbrush (Oral B, Braun) was used with freshly slurries of non-fluoridated toothpaste (Sensodyne Original) with low abrasiveness (table 1), and a ratio of 1 toothpaste to 3 distilled water.[16,17] Toothbrush was applied on the enamel surface that was standardized with a holder, and brushing was continued for 45 seconds using 200 gm load with 40,000 pulsations/minute oscillating at 8,800 movements/minute.[18] Specimens were then inserted in artificial saliva overnight (20 hours), that was renewed daily: thus simulating 48 days of oral environment.[19]

Application of preventive treatment modalities

After subjecting the specimens to erosion/abrasion challenge, the preventive materials (table 1) were applied: In Group 1 (Artificial saliva), no treatment was performed. In Group 2 (PRG barrier coat), one drop of the liquid activator was applied on the powder base in the container and mixed using the disposable brush provided by the manufacturer, which was applied in a thin layer on the dried enamel surface within 2 minutes from mixing. It was then, left undisturbed for 5 seconds, then light-cured using RTA mini-S light cure unit, 1000 - 1200 mW/cm^2 (Guilin Woodpecker Medical Instrument) for 10 seconds and checked for complete curing. For Group 3 (NaF varnish), NaF varnish was applied on the dried enamel surface in a thin layer using micro brush. Group 4 (NaF varnish + PRG barrier coat), combined application was performed by using NaF varnish first on the dry enamel surface, followed by gentle rinsing (according to manufacturer instructions) and drying before the application of the PRG barrier coat, which was applied as mentioned above and light-cured for 10 seconds.

All specimens of the four groups remained in artificial saliva for 4 hours before subjecting them to the second challenge.

Cyclic Erosion/Abrasion Challenge after preventive treatment

Erosion and abrasion cycles were then repeated for 3 consecutive days as mentioned above simulating 48 days, providing a total of 96-days simulation of oral environment for the whole experimental study.

Microhardness Evaluation

Microhardness was measured using a micro-Vickers hardness tester (Tukon 1102 Wilson hardness tester Buehler, Germany). Vickers test was used with 50g load applied smoothly without impact, forcing the indenter into the test specimens. The indenter was held in place for 10 seconds, in which physical quality of the indenter and accuracy of the applied load were controlled. After the load was removed, the indentation was focused using a magnifying eyepiece and the two impression diagonals were measured, and approximated to the nearest 0.1μm with a micrometer. Three readings for each specimen were obtained and averaged. The Vickers hardness (HV) was calculated using $HV = 1854.4\ L/d^2$, (L: load, d: diagonal).

Surface Roughness Evaluation

Surface roughness measurement was performed using SJ-210 Portable Surface Roughness Tester, (Mitutoyo, Japan). Each specimen was fitted to the specimen holder with the specimen surface just touching the measuring tip. Device calibration was done using the standard calibration specimen before use. Testing parameters were: measuring distance of 4 mm, measuring speed 0.5 mm/sec, returning 1mm/sec, and measuring force 0.75 mN, Stylus profile was: tip radius 2 microns, tip angle 60 degrees. Evaluation parameter was Ra value (expressed in microns): 3 readings were recorded for each specimen at a distance of 500 μm each.

Statistical Analysis

Statistical analysis was done using IBM© SPSS© Statistics version 23 (IBM© Corp., Armonk, NY, USA). Numerical data were expressed as median and range. Comparison between the four groups was done using Kruskal-Wallis. Friedman test was performed for comparison within each group. All tests were two-tailed. A p-value < 0.05 was considered significant.

TABLE (2) Showing the volume of NaOH needed at different pH values

pH	4.5	5	5.5	6	6.5	7
Volume (mL)	6.4	8.1	9.7	11.4	12.5	13.2

RESULTS

Microhardness and Surface roughness

The comparisons between groups and within each group are outlined in Tables 3, 4, 5, and 6. In comparison to baseline, the first cycling before treatment decreased microhardness and increased the surface roughness within each group. Meanwhile, all treatments after second cycling increased microhardness and decreased the surface roughness of eroded-abraded enamel within each group. At all levels of the study, there was a statistically significant difference between the experimental times (baseline, first cycling before treatment, and second cycling after treatment) with $p < 0.05$, as shown in Tables 3 and 4. While the comparison between all groups at all times revealed no significant difference regarding microhardness and surface roughness (Tables 3, 4).

Relative to baseline readings, the percentage change of first cycling before treatment showed no significant difference between all groups in microhardness and surface roughness ($p = 0.320$ and 0.346, respectively); see Table 5.

The comparison between all groups on % change regarding microhardness and surface roughness for second cycling after treatment relative to first cycling before treatment is shown in Table 6. The highest increase in the median % change of enamel microhardness was recorded for NaF varnish, followed by NaF varnish + PRG barrier coat, followed by the Artificial saliva group, then PRG barrier coat (30.4%, 16.0%, 14.5%, and 12.1%, respectively). There was no significant difference between the groups (p =0.119). Regarding the surface roughness, the highest median % change of decrease was recorded for the NaF varnish + PRG barrier coat group, followed by the Artificial saliva group, followed by the NaF varnish group, and then the PRG barrier coat group (-36.5%, -35.0%, -30.1%, and -24.6%, respectively), with no significant difference between all groups (p =0.248).

TABLE (3) Microhardness (gf/μm^2) of the four groups at baseline, after first erosive-abrasive challenge and after treatment and second erosive-abrasive challenge

	Artificial saliva	**PRG barrier coat**	**NaF varnish**	**NaF varnish + PRG barrier coat**	**Chi-Square***	**p-value**
Baseline	374.6 (302.6, 394.6)	339.7 (274.9, 377.5)	325.7 (295.7, 378.6)	369.0 (261.0, 382.4)	5.327	0.149
First erosive-abrasive challenge before treatment	106.3 (88.6, 155.7)	129.1 (102.2, 235.4)	125.1 (106.1, 137.7)	124.6 (114.5, 166.9)	3.734	0.292
Second erosive-abrasive challenge after treatment	133.5 (114.5, 175.4)	152.4 (115.2, 260.7)	163.1 (143.5, 211.6)	181.6 (132.8, 205.6)	7.576	0.056
p-value	0.001	0.001	0.001	0.001		

Data are presented as Median (range) **** Kruskal-Wallis test***

TABLE (4) Surface roughness (μm) of the four groups at baseline, after first erosive-abrasive challenge and after treatment and second erosive-abrasive challenge

	Artificial saliva	**PRG barrier coat**	**NaF varnish**	**NaF varnish + PRG barrier coat**	**Chi-Square***	**p-value**
Baseline	0.369 (0.247, 0.933)	0.483 (0.245, 1.504)	0.668 (0.279, 0.868)	0.373 (0.261, 0.557)	3.659	0.301
First erosive-abrasive challenge before treatment	0.654 (0.518, 1.174)	1.225 (0.484, 1.768)	0.966 (0.592, 1.287)	0.676 (0.596, 0.876)	5.66	0.129
Second erosive-abrasive challenge after treatment	0.425 (0.336, 0.901)	0.986 (0.295, 1.333)	0.676 (0.244, 1.045)	0.384 (0.336, 0.646)	6.243	0.100
p-value	0.005	0.004	0.004	0.002		

Data are presented as Median (range) **** Kruskal-Wallis test***

TABLE (5) Percentage of change in microhardness and surface roughness after first erosive-abrasive challenge relative to baseline

Group	% Change of Microhardness			% Change of Surface Roughness		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Artificial saliva	-67.6	-77.6	-59.0	61.0	25.9	164.5
PRG barrier coat	-62.6	-70.4	-32.3	68.7	17.6	299.5
NaF varnish	-61.40	-72.00	-58.30	57.3	33.5	137.5
NaF varnish + PRG barrier coat	-66.7	-68.1	-36.0	79.7	56.3	185.8
p-value		0.320			0.346	

TABLE (6) Percentage of change in microhardness and surface roughness after treatment and second erosive-abrasive challenge relative to first erosive-abrasive challenge before treatment

Group	% Change of Microhardness			% Change of Surface Roughness		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Artificial saliva	14.5	8.4	37.0	-35.0	-40.2	-23.2
PRG barrier coat	12.1	8.0	53.2	-24.6	-39.0	-19.5
NaF varnish	30.4	14.2	68.6	-30.1	-58.8	-18.8
NaF varnish + PRG barrier coat	16.0	9.9	53.6	-36.5	-51.7	-25.8
p-value		0.119			0.248	

DISCUSSION

The present study was designed to provide minimally invasive treatment, as the first line of management for the clinical situation to prevent enamel erosion and its consequences, that might occur due to the high consumption of energy drinks, that is widely used nowadays. This study evaluated the different preventive treatments using NaF varnish, PRG barrier coat, combined application of both materials and the artificial saliva as negative control, when challenged under erosion/abrasion using energy drink (Red bull). The microhardness (VHN) and surface roughness (Ra) values of enamel samples were evaluated prior and after various preventive treatments.

Based on the results attributed from this study, it was found that the microhardness of enamel samples decreased after subjected to the erosion/abrasion challenge with significant difference. Meanwhile, there was no statistically significant difference among the tested groups at baseline. The enamel specimens regained their microhardness after being exposed to different preventive treatments, even though they were subjected to another challenge. Despite this, there was a statistically significant difference, that co-existed among baseline and after material application, which means that although the VHN increased, none of the treated groups had reached the baseline. Moreover, there was no significant difference between the different materials regarding the microhardness values. The highest increase in VHN was recorded with NaF varnish, followed by NaF varnish+ PRG barrier coat, then artificial saliva group and the lowest value was recorded with PRG barrier coat with insignificant difference between all groups.

These results were in convenience with Valian et al.,[20] who concluded that NaF varnish improved the enamel microhardness, but their results documented, that it reached that of sound enamel, and this was in contradiction with the present study, which might be due to the different methodology protocol, as they applied the materials after the challenge and not subjecting them to another challenge after their application. Additionally, Sar Sancakli et al.[6] results agreed with the findings of the present study, in which they found that the single application of fluoride varnish had the ability to prevent enamel erosion, yet in their study they used different formulations of fluoride, finding out that their formulations showed better results than the NaF varnish. According to Kaga et al.[21] in their study, they claimed that the S-PRG barrier coat had the ability to inhibit demineralization action, when applied on enamel surface in lactic acid, also they found out that it had the ability to neutralize the pH of the acidic media, due to the release of several ions as sodium, barium, fluoride, and aluminum enhances the buffering effect. These results were in convenience with the results of the present study, despite the different protocols used for inducing erosion lesions. However, on the contrary Spinola et al.[11] found out that NaF varnish did not prevent the mineral loss in comparison to the S-PRG barrier coat under pH cycling. This contradiction might be due to the different concentrations of S-PRG used in their study, in which 20%, 30% and 40% were used, as well as they performed their study under demineralization and remineralization challenge.

Regarding the surface roughness results, there was a significant difference from that at the baseline, after subjected to erosion/abrasion challenge. Meanwhile, there was significant decrease in the Ra values after the application of different preventive treatments when subjected to the second erosion/abrasion challenge. The highest Ra value was observed with the PRG barrier coat and the lowest was observed with the combined application of PRG barrier coat and NaF varnish, meanwhile there was no significant difference among all groups. Artificial saliva showed insignificant difference, when compared with other preventive materials regarding the surface roughness and microhardness results. This might be due to its ability to counteract the enamel loss under challenges containing hundreds of proteins that serve as protection for enamel, together with its buffering capacity, and the presence of calcium and phosphate which aid in remineralization, limiting the erosive potential associated with the energy drinks.[22,23] Furthermore, another study on comparing artificial saliva with different forms of NaF showed comparable Ra values. This might be due to physical removal of the varnish, which possibly alter the properties of the enamel surface, complicating the assessment strategy from the residual presence of the coating.[24] In the current study brushing was done in conjunction with the erosion, which might aid in the removal of the varnish.

On contrary, Bezerra et al.[25] results were in contradiction with those of the current study, as they observed that NaF varnish did not show the protective effect against the erosion/abrasion challenge in comparison to the hybrid coating material used in their study. They found that it had lower resistance against mechanical action of tooth brushing, yet it was efficient when subjected to erosion only. When NaF is applied to enamel surface, water from saliva penetrates the varnish and dissolves the salt leaving a layer of CaF_2 on the enamel acting like a reservoir layer, this action leads to degradation and softening of the varnish layer, which will soon be easily removed by different actions as brushing or eating. Therefore, the manufacturer recommends delaying of eating and brushing after its application for several hours, despite this, it will be lost within a short period leaving the CaF_2 layer for continuous release of fluoride that acts upon low pH, which also can affect the surface roughness of enamel.[11,26,27] Regarding the PRG barrier coat, it was assumed by the manufacturer that it will act as a pellicle that could remain for several weeks, meanwhile according to Spinola et al.,[11] brushing aids in the removal of this layer, but they found that the varnish will be retained on the surface in areas that are difficult to be reached by toothbrushing. This was consistent with the results of the present study, that showed that the PRG barrier coat showed the highest surface roughness of all groups with insignificant difference, yet it showed an improvement in surface roughness when compared to the first challenge. The different surface effects of PRG barrier coat when modified with the NaF varnish showed improved protection against erosions/abrasions, and this seems to be related to their better ability to adhere to the tooth surface, that allows their increased contact, and therefore prolonging their action with enhancement of their wear-resistance under the action of the mechanical brushing, thus improving the enamel surface roughness. Notably, Strontium has the capacity to enhance remineralization, with a synergistic effect being observed when it is applied in conjunction with Fluoride. The combination of Strontium and Fluoride could be advantageous for replacing hydroxyl and calcium ions in the apatite structure.[28] Ions released from S-PRG filler had an acid-buffering action in the low pH, as several ions released, plays an important role in pH neutralization, leading to inhibition of enamel demineralization at early stages.[21] Therefore, based on the results of the current study, the first null hypothesis that there is no difference between all variables against erosion/abrasion challenge of enamel is accepted. Furthermore, the second null hypothesis, which assumes that the microhardness (VHN) and the surface roughness (Ra) values after different treatment protocols subjected to erosion/abrasion challenge will reach the baseline values is rejected, as they were not effective to recover the enamel integrity specimens evaluated at baseline.

In the current study, effort was done to mimic the intraoral environment as much as possible, however it is difficult to totally reproduce the clinical condition and should only be interpreted as prediction of the relative erosion potential of the energy drink. As stated by many studies, erosion is a multifactorial condition and its occurrence and development depend on many risk and protective factors, as well as their interplay. In addition, the erosive potential of any dietary substance depends on multiple factors, as frequency of acid intake, individual dietary habits, the physical properties of these agents, flow rate, composition and clearing capability of saliva, all these factors influence the progression of the erosion.[29] Despite the limitation of the current study, it could be claimed by the findings that eroded/abraded enamel can be ceased and improved by the application of the PRG barrier coat giving similar results as the NaF varnish, as well as the combined application of both materials.

CONCLUSION

Under the limitation of the current study, it could be concluded that:

1. Energy drink decreased the microhardness of enamel and increased the surface roughness.
2. All preventive materials used increased the microhardness and decreased the surface roughness of all enamel specimens under erosion/abrasion challenge.
3. Artificial saliva did counteract the erosion progression in all groups, increasing the microhardness and decreasing the surface roughness.
4. At all levels of the study the baseline microhardness and surface roughness were not regained.

Author Contributions

Z.O.T. and N.K.H.: Conceptualization; Methodology; Validation; Formal analysis; Investigation; Resources; Data Curation; Writing – original draft preparation; Writing – review and editing; Visualization; Supervision. H.S.H.: Conceptualization; Validation; Writing – review and editing; Visualization; Supervision. E.H.: Conceptualization; Methodology; Investigation; Writing – original draft preparation and editing.

Competing Interests

The authors declare that they have no competing interests.

Ethics Approval and Consent to Participate

Ethical approval was granted by the Research Ethics Committee of Faculty of Dentistry, Cairo University (number:181022).

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