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Research / Araştırma Makalesi

Remineralization Potential of Ginger-Honey on Initial Enamel Lesions of Different Depth

Zencefil-Balın Farklı Derinlikteki Başlangıç Mine Lezyonlarında Remineralizasyon Potansiyeli

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ABSTRACT

Background: The study aims to explore the remineralization efficacy of toothpaste with the active ingredients of ginger and honey on in-vitro produced early dental caries lesions by using ultrasound, FluoreCam, surface microhardness and light and scanning electron microscope methods.

Methods: Total of 105 enamel samples were divided into three main groups which were exposed to a demineralizing solution for 18 (D1), 36 (D2), and 72 (D3) hours to take initial measurements by ultrasound, FluoreCam, and surface microhardness, SEM. All main groups were divided into three subgroups each then, topically applied a toothpaste with NaF content (R1N) and a dental toothpaste with ginger-honey content (R1G) (Gumgumix) by a toothbrush 3x1/day for five minutes and stored in remineralizing solution, measured at the end.

Results: Toothpaste with ginger-honey content produced significant remineralization results (p=0.033) on the 52-micron initial enamel lesions (D1) by microhardness. Similarly, the FluoreCam size (p=0.001), microscope (p<0.001) and microhardness (p=0.001) results of the 80-micron lesion distinctly showed remineralization. In the 140-micron lesions (D3), the FluoreCam, microscope, and microhardness marked some changes on demineralization while the ultrasound detected the changes on both the demineralization and remineralization (p=0.035, p=0.025). When the remineralization and demineralization variations were compared, the ultrasound method, along with the microhardness, control, method, appeared to be the only method that differed in all groups in general. In addition, the dental toothpaste with ginger-honey content produced the highest remineralization values.

Conclusion: As a result, the application of the dental toothpaste with ginger-honey content produced enhanced remineralization effect in all demineralized groups.

Keywords: Initial enamel Lesion, Ginger, Honey, Remineralization, Ultrasound, Fluoresence.

ÖZ

Amaç: Bu çalışma, deneysel olarak oluşturulmuş başlangıç çürüklerinde etken maddesi zencefil ve bal olan diş macununun remineralizasyon etkinliğinin ultrason, FluoreCam yüzey mikrosertlik ölçüm metodlarıyla tespit edilmesini amaçlamıştır.

Gereç ve Yöntem: Toplam 105 adet mine örneği 3 ana gruba ayrılarak 18 (D1), 36 (D2) ve 72 saat demineralizasyon solüsyonu içerisinde bekletilerek başlangıç ölçümleri ultrason, Fluorecam ve yüzey mikrosertlik, SEM ölçümleri alınmış, tüm derinlik grupları 3'er gruba ayrılarak NaF içeren diş macunu (R1N) zencefil-bal içeren diş macunu (R1Z) (Gumgumix) günde 3 defa 5 dk boyunca diş fırçası yardımı ile topikal uygulanmış ve remineralizasyon solüsyonunda bekletilerek ölçümleri alınmıştır.

Bulgular: Çalışmamızda da 53 mikronluk başlangıç mine lezyonlarında (D1) zencefil-bal içeren diş macunu anlamlı remineralizasyon değerleri vermiştir (p=0,033). Aynı şekilde 80 mikronluk lezyonun (D2) FluoreCam size (p=0,001), mikroskop (p<0,001) ve mikrosertlik (p=0,001) sonuçlarında da remineralizasyon bariz olarak gözlenmiştir. 140 mikronluk lezyonlarda (D3) FluoreCam, mikroskop, ve mikrosertlik tarafından değişim fark edilirken, ultrason da gerek demineralizasyon gerekse remineralizasyon değişimlerini fark etmiştir (p=0,035, p=0,025). Remineralizasyon ve demineralizasyon farkları kıyaslandığında, genel olarak tüm gruplarda ultrason metodu, mikrosertlik kontrol metodu ile uyumlu olarak fark gösteren tek metot olmuştur. Ayrıca genel değerlendirmede zencefil-bal içeren diş macunu en yüksek remineralizasyon değerlerini vermiştir.

Sonuç: Zencefil-bal içeren diş macunu uygulanması, tüm demineralizasyon derinliği gruplarında üstün remineralizasyon etkisi göstermiştir.

Anahtar Kelimeler: Başlangıç mine lezyonu, Zencefil, Bal, Remineralizasyon, Ultrason, Floresans.

INTRODUCTION

Although largely preventable, dental caries remains the most prevalent chronic disease observed throughout all stages of human life.[1] It involves a balance between demineralization and remineralization with dental plaque and its secreted acids, which result in a long-term critical pH drop and cavity formation.[2] Today, the "minimally invasive treatment approach" principle is adopted in the treatment of dental caries[3]. According to the minimally invasive approach principle, if dental caries is diagnosed at the initial stage, it is recommended to treat them by approaches such as regulating the diet, better controlling the formation of plaque, and using appropriate fluoride components, remineralization agents.[4,5]

Remineralization agents are used to stabilize tooth structure early in the caries stages before invasive treatment is performed. This concept is popularized with new approaches to make oral care products with natural ingredients as more patients are looking for alternatives that are "natural" or "herbal" products. Promising natural agents such as honey and ginger extracts have recently been developed and applied in toothpaste ingredients for their immunomodulatory, antimicrobial, anti-inflammatory, and anticancer properties, particularly for oral health. However, there is still limited in vitro study on its remineralization capability in early caries lesions (ECL) under an erosive condition.[6]

Today, the interest in natural products is ever increasing due to the side-effects of synthetic materials and their negative impact on nature.[7,8] Many herbal products such as clove oil, turmeric, eucalyptus oil, ginger, garlic, cocoa, and rosemary have been studied and demonstrated to have varying degrees of antibacterial effectiveness as reported in a comprehensive literature search and analyses.[9]

The accurate measurement of newly developed and routinely used remineralization agents, as well as the level of demineralization itself, is crucial for the proper interpretation of the results. Considering that visual inspection[10] and radiographic methods[11] exhibit low sensitivity and high specificity, the present study focused on non-invasive and non-subjective diagnostic methodologies.

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The present study aimed to investigate the remineralization potential of a ginger-honey containing toothpaste on initial caries lesions at different depths using ultrasound, FluoreCam, surface microhardness and light and scanning electron microscope methods.

MATERIAL AND METHOD

The ethical approval was obtained from the Ethics Board of Faculty of Dentistry of Bursa Uludağ University for the study (Decision No: 2015-11).

Selection and Preparation of Tooth Samples

Study flowchart is in the **Figure 1**.

Enamel samples were prepared from the middle 1/3 mesiobuccal surfaces of the freshly extracted impacted third molars teeth by using of a diamond disc under the water cooling (Mecatome T180, PRESI, France). The enamel samples obtained were put into silicone molds (Siladent, Silaform 90 extrahart, Dr. Böhme & Schöps GmbH, Germany). The sample surfaces were sanded using silicone carbide discs no. 600 for five minutes and polished using a polishing gel for 10 minutes (Mecatech 234, PRESI, France). Afterward, the samples were rinsed with distilled water and stored in a container of distilled water at +4°C in the refrigerator for 24 hours until measurements.

A waterproof tape measuring 2x2 mm was placed at the center of the enamel surface of each sample. To protect the areas outside the taped region from the pH cycle model, these parts were coated with an acid-resistant polish (Nailcare, Flormar, Turkey).

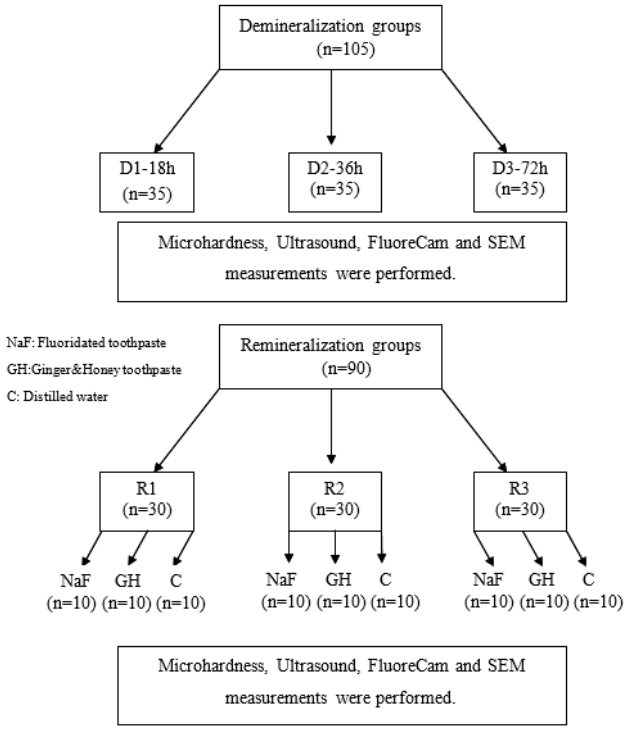

Figure 1. The study flowchart

Measurements

Microhardness

The enamel samples within the silicone molds were extracted from the distilled water container and subsequently dried using a thin paper towel. The sample was then placed in the device with the enamel surface facing upwards to measure the microhardness values by applying a 200-g load force for 15 seconds with the Vickers measuring tip (Leco LM247AT, Leco Comp., MI, U.S.). Each sample was measured three times to determine the mean hardness values.

Ultrasound

The enamel samples in the silicone molds were removed from the distilled water container and dried with a thin paper towel. The ultrasound gel was applied on surfaces and the probe (Novascope 4500, Harisonic, Staveley NDT, Kennewick, Wash, U.S.) was hold on with 90º to the tooth surface and appropriately rolled over the surface till to obtain the waves in right way.

Fluorescence (FluoreCam)

Samples placed in acrylic molds and soaked in distilled water were dried with paper towels after demineralization. Images of the demineralized surfaces were captured using the intraoral camera of the FluoreCam system (Daraza Corporate Headquarters, Indiana, USA). The analyses were stored in the FluoreCam Software program. Both qualitative and quantitative analyses were performed on the demineralized areas outlined by the red lines. The measurements were recorded as size, intensity, and impact values.

Scanning Electron Microscope (SEM)

5 samples from each of the three demineralization groups were selected for histological examination. Enamel samples stained with a solution containing 0.5% basic fuchsin in propylene glycol were brushed for 10 seconds using a brush and then rinsed with tap water. Subsequently, the samples were divided into two parts at the center of the lesion using a microtome device (ISOMET 1000 Buhler, USA) underwater. The SEM (ZEISS EVO LS 10, Germany) images of the sagittal section of the enamel samples were photographed for each group at X500, X1000, and X2500 magnification. The boundaries of the staining obtained by each section were examined under a stereomicroscope (Leica MZ7.5, Germany) at 64x magnification. The depths were measured three times and the average values were recorded by ET.

Demineralization procedures

A random selection was made among the prepared 105 enamel samples to form three groups (n=35). For the demineralization of the samples, the demineralizing solution (pH 4.7) developed by Amaechi et al. (1998)[12] was used:

2.0 mmol/lt $Ca(NO_3)_2.H_2O$

2.0 mmol/lt $NaH_2PO_4.H_2O$

0.04 µg f/ml NaF in 75 mmol/lt acetate buffer

The samples were then placed into 500ml- and 250-ml beakers with the enamel surfaces facing upwards, and all beakers were placed into the shaking incubator (ZWYR-240, LABWIT, Australia).by groups.

They were shaken at 37°C and 60 rpm, with the solution being replaced daily to form the initial enamel lesions. Group D1, group D2, and group D3 were removed from the demineralizing solution after 18 hours, 36 hours, and 72 hours, respectively, and rinsed with distilled water. The samples were stored in containers containing distilled water in the refrigerator at +4 °C for post-demineralization measurements.

Remineralization procedures

The samples were then subjected to the pH cycle process based on their respective groups in 500, 250, and 100-ml beakers (Amechi, 1998).

remineralizing solution (pH 7.0):

1.5 mmol/lt $Ca(NO_3)_2.H_2O$

0.9 mmol/lt $NaH_2PO_4.H_2O$

150 mmol/lt KCl

0.05 µg F/ml NaF in 0.1 mol/lt cacodylate buffer

demineralizing solution (pH 4.7):

2.0 mmol/lt $Ca(NO_3)_2.H_2O$

2.0 mmol/lt $NaH_2PO_4.H_2O$

0.04 µg F/ml NaF in 5 mmol/lt acetate buffer

The samples placed in the beakers for remineralization were shaken at room temperature (20-22°C) and 70 rpm and stored in the shaking incubator (ZWYR-240, LABWIT, Australia). The NaF toothpaste (Glycerin, PEG-8, Hydrated Silica, Pentasodium Triphospate, Aroma, SLS, Sodium Fluoride (1450 ppm)) (İpana Kalsident, Procter & Gamble, Germany) was applied with a toothbrush three times a day for five minutes. Herbal toothpaste (Gumgumix, Beka İlac, İstanbul, Turkey) with ginger-honey content (15% ginger, 7.5% honey, dicalcium phosphate, calcium carbonate, glycerin, water, calcium carboxymethyl cellulose, aroma, sorbitol, menthol, Cocamidopropyl betaine, xanthan gum, saccharin, potassium sorbate) was again applied three times a day for five minutes (**Figure 2**), in each case on the sample surfaces which were afterward rinsed with tap water and suspended in the remineralizing solution. The control group samples were stored in artificial saliva set as the remineralizing solution for the same periods. Each group was kept in the remineralizing solution for 18 hours and demineralizing solution for 6 hours for seven days whichs was intended to emulate daily eating habits.

Figure 2. The dental toothpaste with ginger-honey content (Gumgumix, Beka Pharmaceuticals, Istanbul, Turkey)

Statistical analysis

In this study, descriptive characteristics were analyzed using n and % values for categorical data, and mean ± standard deviation values for continuous data. One-way ANOVA was employed for the comparison of continuous variables. An alpha error level of 5% was considered the threshold for statistical significance. All analyses were conducted using the SPSS 20 software.

RESULTS

Post-demineralization outcomes

Fluorecam

Upon examining the images taken from the samples after demineralization, it is observed that the demineralized area, surrounded by red, increases proportionally with the demineralization duration. The size of the demineralized area is expressed as FluoreCam Size, with the following average values obtained: 1.11±0.85 for D1 (18 hours of demineralization), 2.36±1.76 for D2 (36 hours of demineralization), and 8.91±3.69 for D3 (72 hours of demineralization) (**Figure 3A**). These values are statistically significant ($p < 0.001$), indicating that the results are consistent with the duration of demineralization.

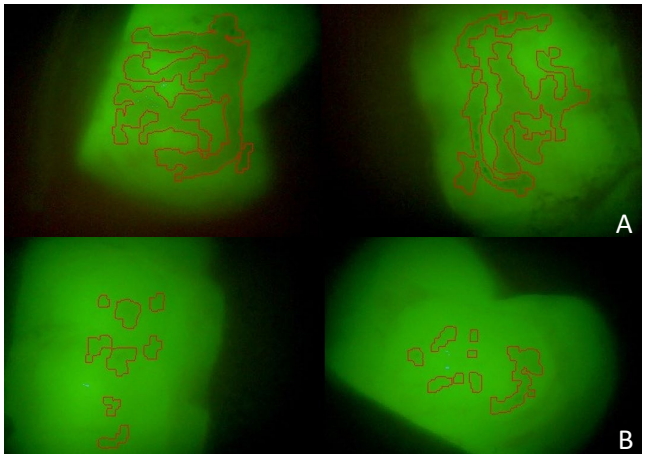

Figure 3. Post-demineralization (A) and post-remineralization (B) FluoreCam measurements in the third demineralization depth group (D3)

Light microscope

In light microscopy measurements after demineralization, a significant difference was observed between the groups, which was proportional to the demineralization duration. The average lesion depths were found to be 53.18±7.36 µm for D1 (18 hours of demineralization), 80.72±10.52 µm for D2 (36 hours of demineralization), and 139.49±5.72 µm for D3 (72 hours of demineralization). These results indicate that lesions of varying depths were successfully obtained as intended (**Figure 4-6**).

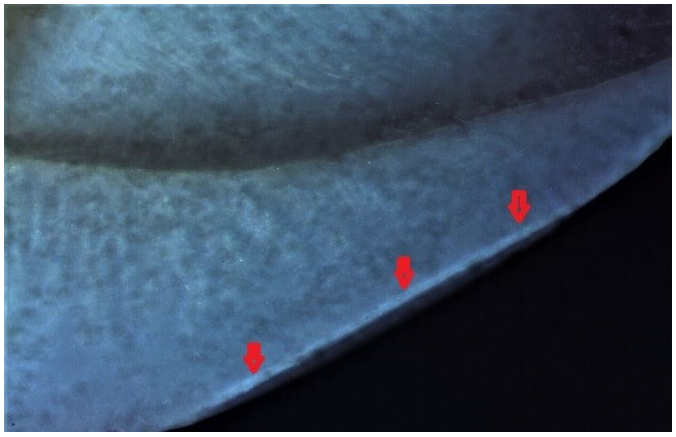

Figure 4. Post-demineralization image of D1 group

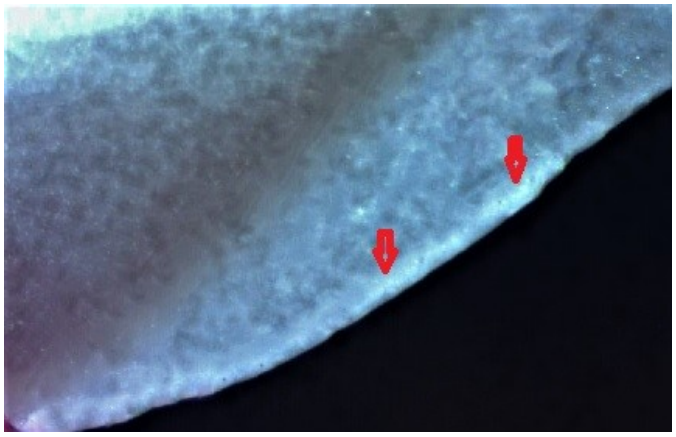

Figure 5. Figure 4. Post-demineralization of D2 group

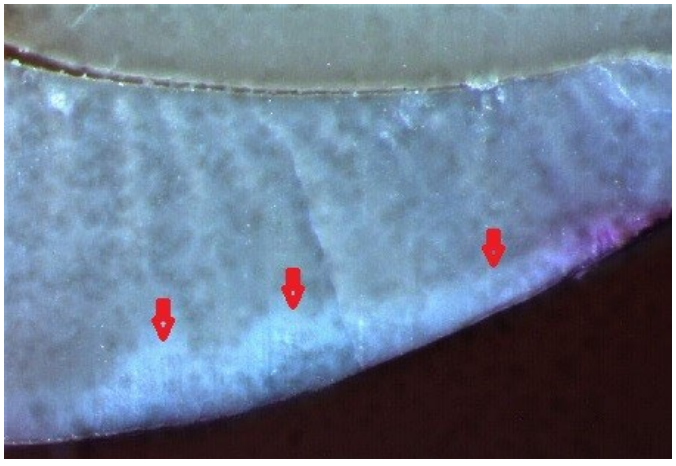

Figure 6. Post-demineralization of D3 group

Scanning electron microscope (SEM)

Sagittal sections of enamel samples were photographed using SEM (ZEISS EVO LS 10, Germany) at magnifications of X500, X1000, and X2500 for each group. Upon examining the SEM images obtained after the demineralization process, it was observed that the enamel had

become highly porous, with inter-prismatic areas expanding due to crystalline dissolution. It was also noted that the demineralization depth increased proportionally with the duration of demineralization, as expected across the groups. In the samples corresponding to the second and third demineralization depths (D2 and D3 groups), tissue loss within the enamel was evident (**Figure 7-9**)

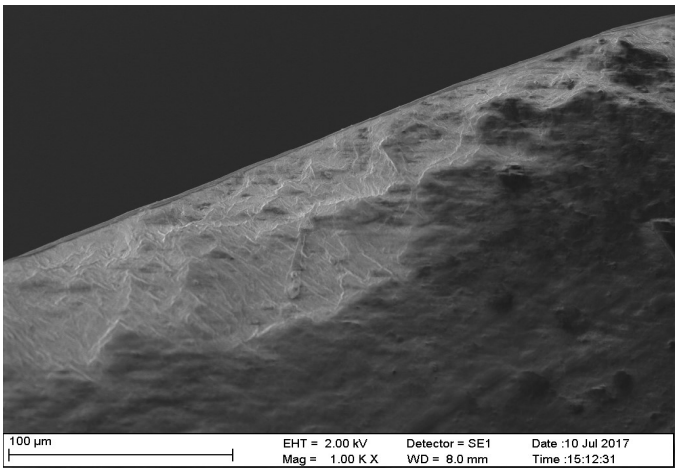

Figure 7. Surface characteristics of D1 group after demineralization procedures.

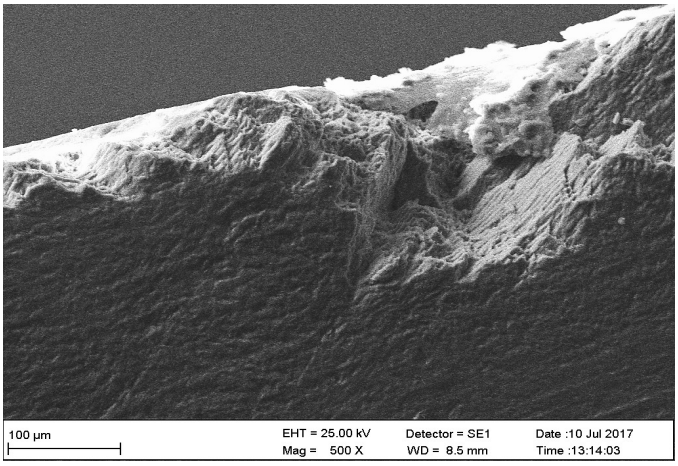

Figure 8. Surface characteristics of D2 group after demineralization procedures.

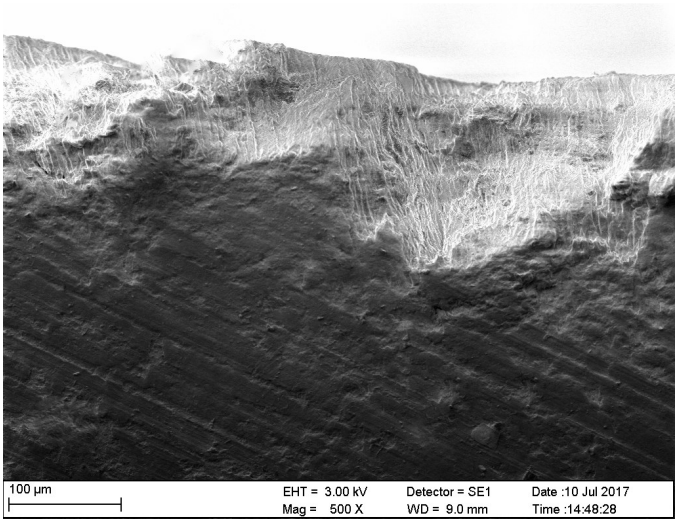

Figure 9. Surface characteristics of D3 group after demineralization procedures.

All test methods demonstrate significant differences in demineralization depth among the groups **(Table 1).** Increase in numerical magnitude of microhardness and FluoreCam change values is found to be associated with an increase in the severity of demineralization, indicating deeper lesions. Similarly, measurements conducted using the ultrasound method show that an increase in the duration of demineralization leads to a higher severity of demineralization, yielding greater numerical values. When comparing between groups, it is observed that the highest demineralization occurs in the D3, D2, and D1 groups, respectively. The ultrasound results are in line with the microhardness results.

Table 1. Differences in demineralization depth among the groups

	Demineralization groups						P[a]
	D 1		D2		D3		
	Mean	SD	Mean	SD	Mean	SD	
Microhardness	293,41	18,24	278,33	13,72	224,99	10,77	**<0,001***
USG	1,31	0,1	1,22	0,25	0,98	0,15	**<0,001***
FluoreCamD (Size)	1,11	0,85	2,36	1,76	8,91	3,69	**<0,001***
FluoreCamD (Intensity)	-9,57	4,91	-9,85	3,97	-17,45	6,32	**<0,001***
FluoreCamD (Impact)	-12,46	12,25	-27,82	30,56	-153,96	70,93	**<0,001***
SEM	53,18	7,36	80,72	10,52	139,49	5,72	**<0,001***

Post-remineralization outcomes

The comparative results of post-remineralization changes are presented in Tables 2A, 2B, and 2C.

Table 2A. Post-remineralization change in R1 samples applied NaF and GH and control

	R1						P[a]
	Control		NaF		GH		
	Mean	SD	Mean	SD	Mean	SD	
ΔMicrohardness	6.29	3.29	10.70	5.79	6.09	10.50	0.284
ΔUSG	.00	.00	.00	.00	.00	.00	**NA***
ΔSize	-.58	.72	-.63	.77	-.77	.94	0.869
ΔIntensity	2.95	5.54	3.37	5.07	3.84	5.16	0.931
ΔImpact	8.14	10.35	9.53	13.10	10.53	13.96	0.913

[a] *One-way ANOVA test*
*Δ Post-remineralization change, *p could not be calculated, SD: Standard deviation*

Table 2B. Comparison of post-remineralization changes in R2 groups

	R2						P[a]
	Control)		NaF		GH)		
	Mean	SD	Mean	SD	Mean	SD	
ΔMicrohardness	5.13	2.64	30.80	9.79	45.16	11.14	**<0.001***
ΔUSG	.00	.00	.00	.00	.00	.00	0.125
ΔSize	-1.16	1.55	-1.85	2.27	-2.12	1.54	0.488
ΔIntensity	2.74	7.45	3.20	3.45	4.97	3.07	0.588
ΔImpact	22.22	40.55	22.15	33.18	24.55	19.89	0.982

[a] *One-way ANOVA test, * p<0.05*

The post-remineralization (R2) change amounts in the second demineralization depth group was not statistically significant in terms of the FluoreCam size, intensity and impact changes and the USG changes. In the ginger-honey group (R2G), the amount of increase in the microhardness level was found to be significantly higher than in the other groups **(Table 2B).**

The post-remineralization (R3) change amounts in the third demineralization depth group showed that the amounts of increase at the FluoreCam intensity, USG, and microhardness levels were significantly higher in the ginger-honey group (R3G) than in the other groups **(Table 2C)**. No statistically significant variation was detected in terms of the FluoreCam size and impact changes **(Table 2C).**

Table 2C. Comparison of post-remineralization changes in R3 groups

	R3						p[a]
	R3C (Control)		R3N (NaF)		R3G (GH)		
	Mean	SD	Mean	SD	Mean	SD	
ΔMicrohardness	5.19	4.19	24.17	7.40	39.42	6.87	**<0.001***
ΔUSG	.00	.00	.00	.01	.01	.00	**0.001***
ΔSize	-5.39	2.48	-9.12	5.69	-8.06	2.58	0.106
ΔIntensity	6.65	5.16	9.39	6.09	13.86	4.58	**0.018***
ΔImpact	109.98	40.23	147.98	93.11	154.14	61.73	0.312

*[a] One-way ANOVA test, * p<0.05*
Δ Post-remineralization change, SD: Standard deviation

The examination based on the demineralization depth groups showed that both the post-remineralization and the post-demineralization FluoreCam size measurements were higher in group D3 than in the other groups (p<0.001, p:0.007). No statistically significant variation was detected between the FluoreCam proximal surface measurements. Both the post-demineralization and the post-remineralization FluoreCam Impact measurements were higher in group D3 than in the other groups. While the post-demineralization FluoreCam Intensity measurements were higher in group D3 than in the other groups, no significant variation was found between the groups in terms of post-remineralization. Both the post-demineralization and the post-remineralization microhardness and USG measurements were found to be lower in group D3 than in the other groups. Some variations were detected across all demineralization depth groups in all testing methods.

The post-remineralization (R1) results in the first demineralization depth group showed that the FluoreCam delta size measurements were lower in the NaF group (R1N) than in the other groups. In the ginger group (R1G), the microhardness levels were found to be higher than in the other groups. No significant variation was detected between the other variables in the post-remineralization groups. (**Table 3**).

The teeth were remineralized after the demineralization process and the change amounts were compared among the remineralization groups (**Figure 10-12**). The post-remineralization (R1) changes in the first demineralization depth group was not statistically significant in terms of the FluoreCam size, intensity and impact changes and the USG changes (**Table 3**).

Table 3. Post-remineralization microhardness changes of the groups

	Control		NaF		Ginger-Honey		P[a]
	Mean	SD	Mean	SD	Mean	SD	
R1 (ΔVHN)	6.29	3.27	10.70	5.79	6.09	10.50	0.284
R2 (ΔVHN)	5.13	2.64	30.80	9.79	45.16	11.14	**<0.001***
R3 (ΔVHN)	5.19	4.19	24.17	7.40	39.42	6.87	**<0.001***

*[a] One-way ANOVA test, * p<0.05, SD: Standard deviation*

When examining the post-remineralization process within the third demineralization depth group (R3), it was observed that the interprismatic areas in the crystalline structure exhibited partial filling and remineralization, which subsequently faded after undergoing remineralization with dental toothpaste containing NaF and Gumgumix, ginger-honey content.

As for the post-remineralization change by the groups in microhardness measurements, the amount of increase in the teeth remineralized with ginger-honey in the second (R2) and third (R3) remineralization groups was found to be significantly higher than in the NaF group and control group. In the first demineralization group, on the other hand, no significant variation was detected based on the methods applied **(Table 3).**

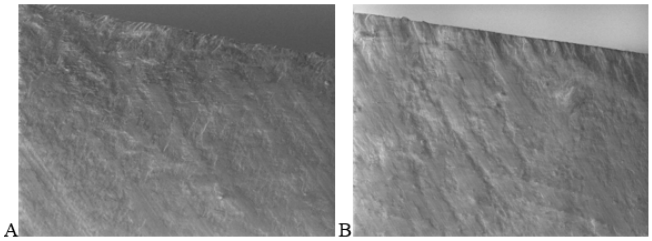

Figure 10. Surface characteristics of R1 group after remineralization procedures with NaF (A) and ginger-honey toothpaste (B)

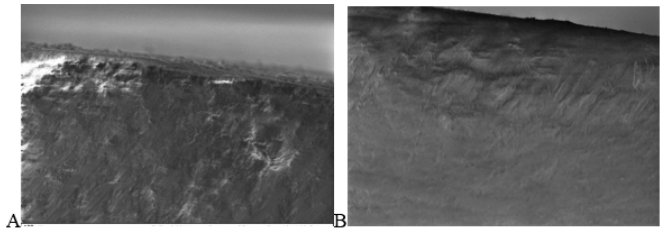

Figure 11. Surface characteristics of R2 group after remineralization procedures with NaF (A) and ginger-honey toothpaste (B)

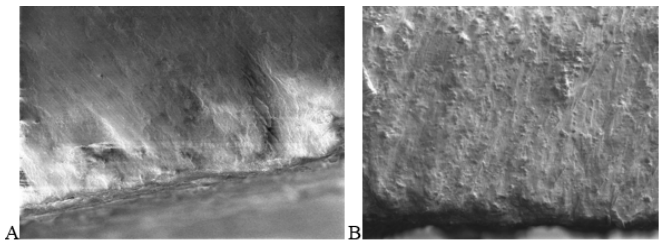

Figure 12. Surface characteristics of R3 group after remineralization procedures with NaF (A) and ginger-honey toothpaste (B)

As for the post-remineralization change by groups in the USG measurements, the amount of change in teeth remineralized with ginger-honey in the third remineralization group (R3) was found to be significantly higher than in the other groups. No significant variation was detected in the first and second remineralization groups (R1 and R2) based on the methods applied.

DISCUSSION

The current study aims to determine the remineralization efficacy of a toothpaste with the active ingredients of ginger and honey at the initial stage of dental caries produced experimentally by ultrasound, Fluoresence, surface microhardness measurement methods.

Bilgin et.al. compared the remineralization efficacy of sodium fluoride toothpaste and casein phosphopeptide-amorphous calcium phosphate, hydroxyapatite and fluoride, fluoride varnish, ginger+honey, ginger + honey + chocolate, and rosemary oil both in situ and in vitro studies and reported that they observed remineralization in all groups.[13] In another study investigating the effect of honey-ginger mixture on the surface hardness of the enamel surface, average surface roughness is 0.244 µm and the microhardness is 256 HV for the positive control flouride, while the same values were found to be 0.241 µm, and 271 HV for honey and ginger.[14] Both studies were compatible with the present study on hardness findings. In present study, the toothpaste with ginger-honey content produced significant remineralization results (p=0.033) in the 52-micron initial enamel lesions. Similarly, the FluoreCam size, microscope and microhardness results of the 80-micron lesion (D2) distinctly showed remineralization as well (p=0.001, p<0.001, p=0.001).

While the lesions at 53-micron depth on average almost remained the same as 52.7 (R1C) microns in the non-fluoride artificial medium after the pH cycle in the post-demineralization light microscope (D1)

measurements, its post-remineralization depth went down to 49 microns after the remineralization with NaF (R1N) and to 45 microns after the remineralization with the toothpaste with ginger-honey content (R1G).

Demineralization-remineralization variation was detected in the 80-micron lesions (D2) only by the microhardness method, and the precipitation caused by the toothpaste with ginger-honey content was found to be far greater ($p < 0.00$) **(Table 1).** A recent study[15] investigating the color change of white-spot lesions exposed to ginger-honey mixture showed enhanced remineralization and acid resistance phase which is consistent with our studies results revealing that the toothpaste with ginger-honey content again achieved the highest remineralization values on 140-micron lesions (D3).

Ultrasound is quite successful method to discern between the soft and hard tissues[16], and appears to be an ideal early caries diagnosis method as it can easily detect the demineralized areas that are yet to develop caries[17]. A clinical study that investigated the in vivo remineralization and demineralization using ultrasound for the first time to clinically diagnose caries reported that the ultrasonic system failed to detect the remineralization and demineralization changes in the 50-86 micron deep enamel lesions[18]. Bab et al. not only reported that proximal enamel and dentin caries could be detected by USG but also defined the so-called "Ultrasonic Caries Detection System' (UCD)[19]. Recently, Kim et al.[20] also showed that high frequency ultrasound distinctly differentiated demineralization within white spot lesions from non-demineralized regions.

Göçmen et al., in their study comparing the effects of NaF, ginger-honey mixture, ginger-honey-chocolate mixture, and rosemary oil mixtures on remineralization in teeth demineralized in vitro, found the changes in the surface microhardness levels statistically significant in all treatment groups and observed the highest statistical significance in the group that used the ginger-honey mixture[21]. In congruence with the aforementioned study, in our study of the 50-micron carious lesion obtained in 18 hours in group D1, the toothpaste with NaF content and the toothpaste with ginger-honey content produced a significant amount of remineralization.

In the study conducted by Talwar et al. (2019)[22], remineralization of three different fluoridated dentifrices (with fluoride concentrations of 5000 ppm, 2500 ppm, and 1100 ppm) on enamel and dentin lesions was examined by ECM (Electric Caries Monitor) and microradiography. The results indicated that the higher fluoride dentifrices did not demonstrate superior remineralization compared to the 1100 ppm fluoride dentifrice for both artificially demineralized enamel and dentin. As our study showed significant remineralization with fluoride toothpaste at varying depths of demineralization, the ginger-honey mixture displayed higher levels of remineralization. Therefore, based on the conditions of the study, it is suggested that instead of increasing the fluoride concentration, the utilization of herbal agents with fluoride may be recommended.

FluoreCam System scans the surface of the tooth with a highly dense light and combines the fluorescence changes, an indirect indication of the changes in the mineral content of the tissues, with the FEI technology to measure the size (FloureCam Size), intensity (FluoreCam Intensity) and impact (FluoreCam Impact).[13,21,23] FluoreCam is highly reliable and valid for in vitro assessments of enamel demineralization[24] in accrodance with our study which determined significancy on all demineralization groups.

Göçmen et al.[21] applied various materials to enamel samples that had been demineralized in vitro for 21 days and measured remineralization using three different methods: QLF, FluoreCam, and microhardness testing. While no significant differences were observed between the groups based on QLF measurements, significant variations were found between some groups in the FluoreCam and microhardness measurements.[21]

Bilgin et al., in their study comparing the use of NaF, CPP-ACP, Remin Pro, and Fluoride varnish, showed that the FluoreCam findings did not match the surface microhardness findings[13].

Korkut et al. showed in their study that FluoreCam could detect the lesions forming around the brackets and achieved successful remineralization with the ginger-honey mixture[25].

Celik et al., showed a remineralization results of ginger, Ginger-Honey-Chocolate and Natural honey applied into enamel samples and detected by FluoreCam[26]. In the current study, according to the FluoreCam results obtained according to the caries depth groups, the Fluore Cam size and FluoreCam Impact measurements of both the post-demineralization and the post-remineralization caries were found to be higher in group D3 than in the other groups. The post-demineralization FluoreCam Intensity measurements were higher in group D3 than in the other groups, whereas no significant variation was found between the groups in terms of post-remineralization.

In the 140-micron lesions (D3), FluoreCam, microscope, and microhardness marked some changes, while the ultrasound detected both demineralization and remineralization changes ($p=0.035$, $p=0.025$). When the remineralization and demineralization variations were compared, the ultrasound method, along with the microhardness control method, appeared to be promising method that recognized the existing difference in all groups overall. In addition, the toothpaste with ginger-honey content produced the highest remineralization values.

CONCLUSION

The application of ginger-honey preparations has the potential to emerge as a viable option for remineralization treatments in the near future. This is due to several factors that make it a promising approach, including its natural composition, cost-effectiveness, and demonstrated efficacy in treating initial enamel caries at various depths.

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Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışmada yer alan verilerin bir kısmı 4-7 Temmuz tarihinde 65nci ORCA Kongresi, Kopenhag-Danimarka'da sunulmuştur.

Bu çalışma, DT danışmanlığında ET'ye ait uzmanlık tezi esas alınarak hazırlanmıştır. Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

Some of the data indicated in this study were presented at the 65th ORCA Congress in Copenhagen, Denmark, from July 4-7.

This study was prepared based on ET's specialization thesis under the consultancy of DT. It is declared that scientific and ethical principles were adhered to during the preparation of this study and that all referenced works are cited in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: ET (%30) DT (%40) FY (%30)
Veri Toplanması | Data Acquisition: ET (%70) DT (%30)
Veri Analizi | Data Analysis: ET (%30) DT (%30) FY (%20) ZCÇ (%20)
Makalenin Yazımı | Writing up: ET (%50) ZCÇ (%50)
Makale Gönderimi ve Revizyonu | Submission and Revision: ZCÇ (%100)

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