International Journal of Medical Science and Dental Health Page No. 83-99

e-ISSN: 2454-9141, p-ISSN: 2455-0779

Volume 09, Issue 12, December 2023

DOI: https://doi.org/10.55640/ijmsdh-09-12-12

EFFECT OF DIFFERENT WHITENING TOOTHPASTES ON SURFACE ROUGHNESS OF YOUNG HUMAN ENAMEL

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ABSTRACT

Purpose: The purpose of this study was to determine the whitening toothpastes effect of surface roughness in young permanent human enamel.

Methods: In this in vitro study, 100 premolars were sectioned, mounted and stored. All teeth were divided into 10 experimental groups (n=10). The specimens were brushed 3600 cycles (equivalent 12-week brushing) with a brushing machine using 25 g of each toothpaste mixed with 40 ml of distilled water. The surface profile of the teeth was measured a profilometric device before and after brushing, respectively. Each teeth surface roughness measured three times and averaged.

Results: In five groups which toothpastes containing bromelain, nano hydroxyapatite, silica, blue covarine and charcoal the decrease in surface roughness was found statistically significant ($p<0.05$), except toothpastes groups containing hydrogen peroxide, sodium hydroxide, microbeads, hydroxyapatite and water. In toothpastes groups containing hydrogen peroxide, sodium hydroxide and microbeads group's surface roughness values were increased but not statistically significant difference between the groups in terms of initial and after brushing surface roughness values.

Conclusion: According to the results of this in vitro study, it can be concluded that, hydrogen peroxide, sodium hydroxide and microbeads based whitening toothpastes increased the surface roughness of young permanent human tooth; had not provide smoother surface on tooth after 3600 cycles brushing. This study emphasizes the need for healthcare professionals to be aware of the whitening products usage for teenagers and make evidence-based decisions when recommending the product to patients.

KEY WORDS: surface roughness, permanent dentition, whitening toothpaste, enamel

INTRODUCTION

The color of teeth plays a crucial role in facial aesthetics, influencing how individuals perceive themselves, interact socially, and, in the end, impacting their psychological welfare (Jamieson et al., 2010).

In young adolescences, the features and facial appearance assume considerable significance, exerting notable effects on self-perception, self-esteem, and overall quality of life (Militi et al., 2021). The desire for whiter teeth has given rise to a new trend, which strongly influenced by the portrayal of perfect and white smiles in the media. (de Mello Rode et al., 2021).

A widely available method for teeth whitening involves the use of toothpaste containing whitening agents (Naidu et al., 2020). Over the last few decades, there has been a significant surge in the popularity of home-based bleaching products (Silva et al., 2021). There are numerous tooth whitening products available, such as, dentifrices, mouth rinses, strips, whitening dental floss, toothbrushes, and paint-on gels or film activated charcoal, oil pulling, etc. Whitening toothpastes are the most common type of over the counter (OTC) products which makes them the primary choice for the method of tooth whitening ((Carey, 2014, Pintado-Palomino et al., 2016). In the market, a variety of toothpaste options offer teeth whitening through diverse mechanisms and agents. Within the market, diverse toothpaste options offer teeth whitening through various mechanisms and agents. These agents include abrasives, enzymes, chemical agents, and optical agents. Abrasives, such as hydrated silica, perlite, and alumina, play a pivotal role in toothpaste formulations, aiding in the physical removal of external stains. (Joiner, 2010). In addition to the typical components found in toothpaste, such as fluoride, active whitening agents like hydrogen peroxide, carbamide peroxide, or sodium citrate are included to chemically whiten enamel. The abrasiveness of toothpaste is contingent on the hardness, size, and shape of abrasive particles. Moreover, tooth abrasion is influenced by factors such as brushing technique, brushing pressure, toothbrush hardness, and the number of brush strokes (Dursun et al., 2023). To assess toothpaste abrasiveness, various techniques have been employed. These include quantitative methods like the relative dentin abrasivity (RDA) method, weight and volume loss techniques, which measure the quantity of abraded material removed. Additionally, qualitative techniques such as profilometer and light reflection methods are used to measure the roughness of the abraded material (Addy et al., 2002).

In the contemporary world, aesthetic considerations regarding one's appearance have become more prevalent among children and adolescents, starting from kindergarten. This growing awareness has led parents to actively seek solutions. While teeth whitening treatments are cautiously administered in adults due to their potential for free radical release and associated toxic effects, concerns have been raised among healthcare professionals regarding the application of such treatments in children (Yazır Kavan & Güven, 2023). Nevertheless, it is recommended for young patients to consult with a dentist, even when using over-the-counter whitening products, excluding whitening toothpastes. This precaution is essential as other products may raise substantial safety and efficacy concerns, particularly in the case of potential long-term overuse and misuse by uninformed individuals (Perić et al., 2018). It is essential to evaluate the impact of these products on the surface properties of dental enamel, particularly concerning surface roughness. Therefore, additional evidence is necessary to thoroughly assess the performance and safety of these products, as relying solely on manufacturers' claims is not a logical approach. Many researches have focused on assessing the abrasiveness of whitening toothpastes. To the best of our knowledge, there is no prior research similar to our study that investigates the surface roughness of permanent young human enamel by comparing all type of whitening toothpaste formulations.

The aim of this study was to determine the all types of whitening toothpastes effect of surface roughness in young permanent human enamel.

METHODS

Ethical aspects

The protocol of the present study was validated by the Marmara University Faculty of Medicine's Clinical Research Ethics Committee with the project number of 09.2021.492.

Sample size calculation

The method of sample size calculation is G*Power software program (version 3.1, Heinrich-Heine Dusseldorf University, Dusseldorf, Germany). This program computed the sample size's power using one-way ANOVA-type power analysis with a 95% confidence interval, an 80% power, and 0.50 effect size values for n = 100. The minimal sample size was determined to be ten samples per group.

Samples preparation and experimental design

The study involved examining the enamel surfaces of 100 recently extracted permanent premolar teeth, which were removed for orthodontic purposes and displayed no signs of decay, surface flaws, or internal discoloration. These teeth were utilized after obtaining written informed consent from the parents of the patients. The samples were cleaned using dental curette immediately after being pulled and kept in distilled water to prevent dehydration. The roots were removed from coronary part in a mesiodistal direction, 1-2 mm below apical region of the enamel-cement joint by a low-speed motor with double-sided diamond discs. A section of approximately 5mm x 5mm in diameter and 2mm in thickness was taken from the middle 1/3 of the teeth. From each premolar, one specimen was created. Samples were polishing with no pumice paste using a low-speed handpiece. The teeth's buccal enamel surfaces were set into molds made of acrylic resin (Imident, Imicryl, Konya, Turkey). All specimens were given numbers and randomly divided into ten groups which included nine experimental and one control group.

The order in which the toothpaste was applied was randomized using the same method. The specialty and details of the toothpastes listed in

Table 1- *Product names, group naming, ingredients, manufacturer.*

Product name and Group naming	Ingredients	Manufacturer
Colgate Optic White Expert (OWC)	Glycerin, Propylene Glycol, Calcium Pyrophosphate, PEG/PPG-116/66 Copolymer, PVP, PEG-12, Tetrasodium Pyrophosphate, SLS, Silica, Aroma, Sodium Monofluorophosphate(1450ppm), Sodium Saccharine, Phosphoric Acid, Hydrogen Peroxide, BHT, Limonene.	Colgate-Palmolive Co., Swidnica, Poland
Opalescence Cool Mint (OPLC)	Sodium Fluoride, Glycerin, Water (aqua), Silica, Sorbitol, Xylitol, Flavor (aroma), Poloxamer 407, Sodium Lauryl Sulfate, Carbomer, Sodium Benzoate, Sodium Hydroxide, Sucralose, Xanthan Gum, CI42090, CI19140, CI77019, CI77891.	Ultradent Products, South Jordan, Utah, USA
İpana 3D White Luxe Intense (IP3D)	Glycerin, Hydrated Silica, Sodium Hexametaphosphate, Aqua, PEG-6, Aroma, Sodium Lauryl Sulfate (SLS), Trisodium Phosphate, Sodium Saccharin, Chondrus Crispus Powder, Cocamidopropyl Betaine, Sodium Fluoride, Xanthan Gum, CI77891, Limonene, Mica, Sucralose, Pearl Powder, Anisyl Alcohol, Sodium Benzoate, Potassium Sorbate.	Procter&Gamble Manufacturing GmbH, Gross-Gerau, Germany
Splat Biocalcium (SPLT)	Aqua, Hydrated silica, Hydrogenated starch hydrolysate, PEG-8, Sodium coco-sulfate, Cellulose Gum, Aroma, Calcium lactate, CI 77891, Sodium bicarbonate, Methylparaben, Hydroxyapatite, PVP, Sodium Saccharin, fish oil, papain, limonene.	Splat-Cosmetica, Russia
R.O.C.S. Sensation&Whitening (ROCS)	Sorbitol, Silica, Glycerin, Aqua, Xylitol,Cocamidopropyl Betaine, Aroma, Xanthan gum, Calcium Glycerophosphate, Bromelain, Magnesium Chloride, Sodium Saccharin, Sodium Benzoate, o-cymen-5-ol, Titanum Dioxide.	DRC Group company, Russia
Dentiste Plus White (DNTS)	Sorbitol, Hydrated Silica, Aqua, SLS, Xylitol, SLS, PVP, Nano hydroxyapatite, Natural green tea extract, Sodium tripolyphospate, Cellulose Gum, Methyl paraben sodium, Sodium Saccharin, Menthol, Titanium dioxide, Ascorbic Acid, Mica, Peppermint Oil, Eucalyptus oil, Clove oil, Sage extract, Chamomile extract, Fennel extract, Glycyrrhiza Extract, Cinnamomum Cassia Bark Extract, CI 42090	Dentiste, Thailand
Colgate Total Advanced Whitening (CT)	Glycerin, Aqua, Hydrated silica, SLS, Arginine, Aroma, Zinc Oxide, Cellulose Gum, Poloxamer 407, Zinc Citrate, Tetrasodium pyrophosphate, Xanthan Gum, Benzyl Alcohol, Cocamidopropyl Betain, Sodium Fluoride, Sodium Saccharin, Phosphoric Acid, Mica, Sucralose, Eugenol, CI 74160, CI 74260, CI 77492, CI 77891	Colgate-Palmolive Co., Swidnica, Poland
Signal White Now Gold (SGNL)	Water, Hydrogenated Starch Hydrolyzate, Hydrated Silica, PEG-32, Sodium Lauryl Sulphate, Lecithin, Oleic Acid, Capryl Glycol, Lauryl Alcohol, Limonene, Cl 74160 (Blue Pigment), Cl 74260 (Green Pigment), Cl 77891 (Titanium Dioxide, Whitening Pigment).	Signal Unilever, UK
Curaprox Black is White (CPRX)	Sodium Monofluorophosphate (0.723%), Potassium Thiocyanate (0.02%), Aqua, Sorbitol, Glycerin, Hydrated Silica, Charcoal Powder, Aroma, Argilla, Decyl Glucoside, Cocamidopropyl Betaine, Sodium Monofluorophosphate, Tocopherol, Mica, Xanthan gum, Hydroxyapatite, Titanium Dioxide, Microcrystalline Cellulose, Maltodextrin, Potassium Acesulfame, Sodium Benzoate, Potassium Chloride, Potassium Sorbate, Menthyl Lactate, Methyl Diisopropyl Propionamide, Ethyl Menthane Carboxamide, Zea Mays Starch, Stearic Acid, Cetearyl Alcohol, Citrus Limon Peel Oil, Citric Acid, Lactoperoxidase, Glucose Oxidase,Amyloglucosidase, Tin Oxide, Sodium Bisulfite, Hydrogenated Lecithin, Limonen, CI75810, CI77289.	Curaprox, Curaden AG, Kimbolton, Switzerland

Nine different content whitening toothpastes were tested in terms of surface roughness in comparison with a regular fluoridated toothpaste. The groups were coded with abbreviations, and samples were coded from 1 to 10 in each group. The groups as follows:

Group OWC: To be brushed with whitening toothpaste containing hydrogen peroxide (Colgate Optic White Expert, Colgate-Palmolive Co., Swidnica, Poland)

Group OPLC: To be brushed with whitening toothpaste containing sodium hydroxide (Opelescence Whitening, Ultradent Products, South Jordan, Utah)

Group IP3D: To be brushed with whitening toothpaste containing microbeads (Ipana 3D White Luxe, Procter&Gamble Manufacturing GmbH, Gross-Gerau, Germany)

Group SPLT: To be brushed with whitening toothpaste containing hydroxyapatite and papain (Splat Biocalcium, Splat-Cosmetica, Russia)

Group ROCS: To be brushed with whitening toothpaste containing bromelain (ROCS Sensation Whitening, DRC Group company, Russia)

Group DNTS: To be brushed with whitening toothpaste containing nano hydroxyapatite and mica (Dentiste Plus White, Dentiste, Thailand)

Group CT: To be brushed with whitening toothpaste containing hydrated silica (Colgate Total 12 Advanced Whitening, Colgate-Palmolive Co., Swidnica, Poland)

Group SGNL: To be brushed with whitening toothpaste containing blue covarine (Signal White Now CC, Signal Unilever, UK)

Group CRPX: To be brushed with whitening toothpaste containing activated charcoal (Black is White, Curaprox, Curaden AG, Kimbolton, Switzerland).

Group CONT: To be brushed with deionized water.

Brushing protocol

The discolored samples were subjected to linear brushing motions using a toothbrushing simulator (MF-100 Tooth Brushing Simulator, MOD Dental, Ankara, Turkey) with the soft bristle toothbrushes. The toothbrushing machine utilized in the study featured six containers and arms that applied horizontal brush strokes, enabling simultaneous brushing of all six specimens. The specimens were fixed in place to minimize movement during brushing cycles. For each group, a mixture formed by combining 25 g of toothpaste with 40 ml of distilled water was used during brushing. All slurries were stirred again before use. The homogeneous solution was applied to cover the entire surface in each container. This brushing process occurred under a static axial load of 200 grams, with a brush length of 10 mm and a speed of 40 movements per second. A total of three thousand six hundred brushing cycles were completed, equivalent to three months of regular oral hygiene practice. The brush heads and paste mix were renewed every 1200 cycles. Following brushing, the samples underwent a 5-minute wash under running water to ensure the removal of any remaining toothpaste residues.

Surface roughness (Ra) measurement

Surface roughness measurement of the samples (n = 100) was carried out in Istanbul Technical University Faculty of Materials Engineering Research Laboratory with surface profilometer device (Veeco Dektat 6M, Stuttgart, Germany). The contact type profilometer was used to measure all the sample's Ra of the baseline and after brushing. Following the placement of the specimen on a customized jig to ensure consistent positioning at the most convex part of the buccal surface for all measurements, the device's needle was positioned on the specimen's surface, and measurements were recorded. For each specimen, three Ra measurements were taken, and the average was calculated.

Statistical analysis

The data collected with Excel documentation, the statistical analysis using SPSS 23 package (SPSS Inc., Chicago, IL, USA). The Shapiro Wilk test was used to reveal the normality of the data ($p > 0.05$). Differences over time in Ra were evaluated with Wilcoxon sign rank and paired t tests, respectively.

RESULTS

Median, minimum and maximum surface roughness values (Ra) of the groups are shown in **Table 2.** Median, minimum and maximum surface roughness values (Ra) of the groups

Groups (n = 10)	Time	Median (µm)	Min (µm)	Max (µm)
OWC	Baseline	1,15	0,72	2,7
	After brushing	1,79	1,26	3,11
OPLC	Baseline	1,53	0,69	3

	After brushing	1,71	1,15	2,31
IP3D	Baseline	1,71	0,46	2,61
	After brushing	1,99	1,23	2,42
SPLT	Baseline	2,7	0,83	4,54
	After brushing	2,62	1,33	3,75
ROCS	Baseline	2,48	1,16	3,12
	After brushing	1,24	0,85	2,65
DNTS	Baseline	1,89	1,11	4,91
	After brushing	1,36	0,68	2,11
CT	Baseline	2,8	1,62	4,35
	After brushing	1,31	0,96	1,64
SGNL	Baseline	2,49	1,06	4,77
	After brushing	1,35	0,68	2,31
CPRX	Baseline	2,2	1,28	3,87
	After brushing	1,31	0,72	2,15
CONT	Baseline	1,66	1,33	2,8
	After brushing	1,46	1,02	1,9

The average of surface roughness values of the groups before (Ra_0) and after (Ra_1) brushing are shown in Fig 1. According to the research findings, there was a statistically significant difference between the groups in terms of Ra_0 and Ra_1 values

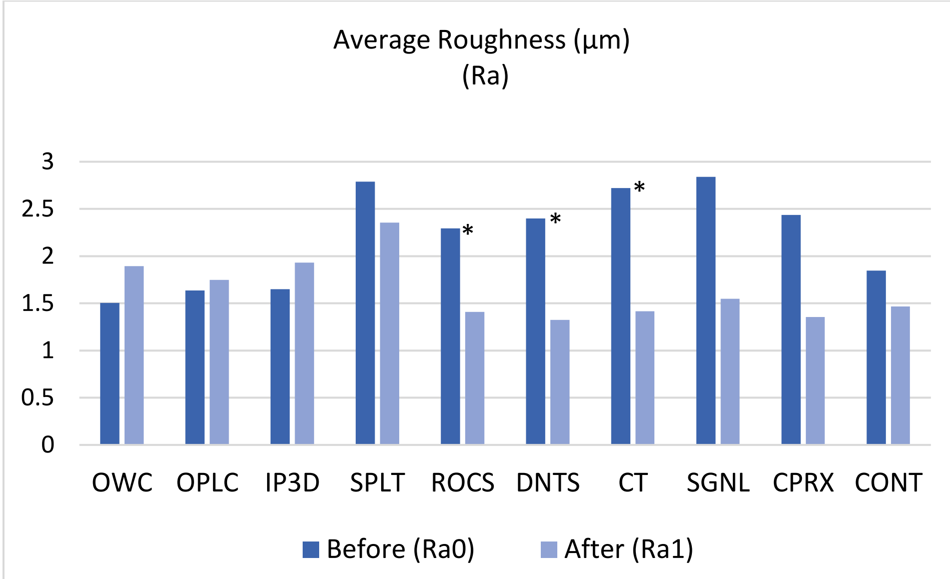

Figure 1. *The surface roughness averages of the groups before (Ra_0) and after (Ra_1) brushing*

The data were not normally distributed as confirmed by the Shapiro–Wilk test. According to Wilcoxon test, there were significant differences among the groups after 3600 cycles brushing. In five groups which toothpastes containing bromelain (ROCS), nano hydroxyapatite and mica (DNTS), hydrated silica (CT), blue covarine (SGNL) and activated charcoal (CPRX) the decrease in Ra was found statistically significant ($p<0.05$), except toothpastes groups containing hydrogen peroxide (OWC), sodium hydroxide (OPLC), microbeads (IP3D), hydroxyapatite (SPLT) and water (CONT)

Table 3. *Statistical analysis of the surface roughness between before and after brushing*

Test statisticsa	OWC	OPLC	IP3D	SPLT	ROCS	DNTS	CT	SGNL	CPRX	CONT
Z tests	-1.784^{b}	-.764^{b}	-.561^{b}	-.051^{c}	-2.803^{c}	-2.090^{c}	-2.497^{c}	-2.701^{c}	-2.497^{c}	-1.682^{c}
P values	.074	.445	.575	.959	.005	.037	.013	.007	.013	.093

In toothpastes groups containing hydrogen peroxide (OWC), sodium hydroxide (OPLC) and microbeads (IP3D) group's Ra values were increased but not statistically significant difference between the groups in terms of Ra_0 and Ra_1 values.

*

*: Statistically significant difference *

*a Wilcoxon Signed Ranks Test

*b Based on positive ranks.

*c Based on negative ranks.

*d the sum of negative ranks equals the sum of positive ranks.

Bolds indicate values significant at $p<0.05$.

DISCUSSION

The present study aimed to investigate the effects of nine different whitening toothpaste formulations on the surface roughness of young permanent tooth enamel in comparison with toothbrushing alone. The study addressed a gap in the literature regarding the impact of whitening toothpastes on young permanent teeth, considering their prevalence and accessibility over the counter.

The study actively engages with prior research, notably referencing studies by Baig et al. (2021), Hamza et al. (2020), Telatar & Bedir (2021), and Yılmaz & Kanık (2022) that have evaluated the relationship between abrasive potential of toothpastes and alterations on enamel and restorative materials. However, the specific impact of whitening toothpastes on young permanent teeth has not been extensively evaluated, and that serves as a primary motivation for the current study.

The formulations being examined consist of a varied array of components, such as hydrogen peroxide, sodium hydroxide, microbeads, hydroxyapatite, bromelain, nano hydroxyapatite, hydrated silica, blue covarine, and charcoal (Vaz et al., 2019). Each of these ingredients has been widely employed in commercially available whitening toothpaste, highlighting the heterogeneity in formulations accessible to consumers. The best of our knowledge, there is not any literature about comparing the surface roughness on the young permanent human enamel with all types of whitening toothpastes.

Several toothbrushing simulators have been proposed in literature with differences in fundamental design principles (Hamza et al., 2020; Ledder et al., 2019). Similar to Hamza et al. (2020) and Dionysopoulus et al. (2023) to confirm standardized brushing parameters, the study employed a computerized brushing simulator. In the present study 3 months brushing (3.600 cycles) was simulated. In accordance with the present study, Schwarzbold et al. (2021) and de Moraes Rego Roselino et al., (2015) have demonstrated that simulating 3,600 brushing cycles over three months, with a focus on minimizing the toothbrush effect by using a soft bristle toothbrush, respectively.

Similarly other studies, the mixture used during brushing was prepared by homogenizing 25 grams of toothpaste with 40 ml of distilled water for each group in our study (Enax et al., 2023; Vieira Vilhena et al., 2022). The combination represents the test mixture specified by ISO standards (ISO 11609-2017).

The surface texture of healthy enamel is determined by the height difference between enamel prisms and the flat areas of hydroxyapatite. Variations in the arrangement of enamel prisms and the organic composition in the interprismatic space can differ among individuals in human tooth enamel (Botta et al., 2009). Surface roughness refers to the parameter that measures the spaced micro irregularities on the tooth's surface texture (Rapone et al., 2022). There are several surface roughness analyze technics such as atomic force microscope (AFM), scanning electric microscope (SEM), optical and mechanical profilometer (Dinçkal Yanıkoğlu & Sakarya, 2020). Profilometer gives the qualitative measurements for the evaluation of abrasivity of a toothpaste. In the conducted in situ study, a concordance between the data obtained through contact and non-contact profilometer has been established (Macdonald et al., 2010). In a recent study, AFM analysis showed no significant difference in surface roughness among control groups, whereas significant variations were detected using a profilometer (Yılmaz & Kanık, 2022). This highlights the importance of method choice, emphasizing the need for careful selection in surface roughness assessments. Accordingly other studies (Ali et al., 2020; Koc Vural et al., 2021; Liljeborg et; Parry et al., 2012), to evaluate the surface roughness, we used mechanical profilometer in our study.

The study actively engages with broader concerns in the literature regarding the adverse effects of whitening toothpaste on dental hard tissue, aligning with findings reported by Jamwal et al. (2022). Discussions surrounding morphological changes and increased surface roughness, as demonstrated by Feitosa et al. and Ozkan et al., contribute to the overall context of potential risks associated with the indiscriminate use of certain whitening toothpastes. According to the findings of the present study, in toothpastes groups containing hydrogen peroxide, sodium hydroxide and microbeads group's surface roughness values were increased but not statistically significant difference between the groups.

Interestingly, the present study found a statistically significant decrease in surface roughness after brushing with toothpastes containing bromelain, nano hydroxyapatite, hydrated silica, charcoal and blue covarine highlighting potential variations in the impact of different formulations. In these groups of toothpaste may have created a polishing effect on human teeth. Moreover, it can be explained with abrasive particles may have filled the rough areas on the surface, creating a smoother surface. A decrease in surface roughness was observed in the control group, where only the effect of the brush was examined. Although not statistically significant, the increase in surface roughness in the toothpaste groups, while trending towards polishing with water and brush, is therefore important.

Recently, the use of natural products worldwide has increased. Cysteine proteases, such as papain and bromelain, are also capable of hydrolyzing large protein molecules. These compounds have

been tested as whitening agents in commercial and experimental whitening products. In addition, such compounds are widely used in other healthcare applications due to their anti-inflammatory,

antithrombotic, and fibrinolytic effects (Schwarzbold et al., 2021). Schwarzbold et al. showed that, with the exception of the papain and bromelain groups, all other groups experienced an increase in surface roughness following 600 cycles of simulated tooth brushing. After 3,600 cycles, only the experimental dentifrice containing papain and bromelain and negative control groups maintained similar roughness values as the baseline evaluation. Conversely, the groups Colgate Optic White exhibited a statistically significant increase in roughness after simulating tooth brushing. These findings support the notion that the toothpaste containing hydrogen peroxide in our study altered surface roughness, but it contradicts the lack of change in surface roughness observed in the toothpaste containing bromelain. The fact that both studies had the same number of brushing cycles but were conducted on bovine teeth, in this study may suggest that different outcomes could arise. Additionally, it is encouraging to compare our findings with that found by Schwarzbold et al., (2021) who found that following 600 brushing cycles, a decrease in surface roughness was observed in the experimental groups where surface roughness had increased, and this reduction persisted after 1200 and 3600 cycles. This finding contradicts a previous study suggesting a linear association between enamel abrasion and the number of toothbrush strokes (Wang et al., 2021).

The inclusion of a negative control group using distilled water adds a valuable dimension to the study, with minimal changes in surface roughness observed. This aligns with findings by Dionysopoulos et al. (2023), highlighting the potential impact of the toothpaste component in providing a smoother surface through interactions with enamel prisms. Additionally, scientific studies have reported that alone brushing with a toothbrush could not the capability to promote a significant increase in surface roughness, but that brushing with toothpaste owing to retention of the abrasive agents in the toothpaste ingredient could affect the surface structure (da Cas et al., 2013; Tellefsen et al., 2011).

Activated charcoal-based toothpaste emerges as a focal point of safety concerns due to its high abrasive potential, echoing recent reviews by Tomás et al. (2023). However, the study introduces a nuanced perspective by highlighting that only one toothpaste containing activated charcoal resulted in a reduction in surface roughness, emphasizing the critical role of formulation in determining its impact. Additionally, a recent review showed that toothpastes based on activated charcoal possess a lower whitening effect than other alternatives and can be considered as less safe due to its high abrasive potential (Tomás et al., 2023). Also, the recent experimental in vitro study showed that the surface roughness of tooth enamel was greater in whitening toothpaste groups with activated charcoal (Zamudio-Santiago et al., 2023). In contrast to this study, our research showed a decrease in surface roughness with toothpaste containing activated charcoal.

Consistent with the results of our study were found in a review by Joiner et al. which concluded that the blue covarine containing whitening toothpaste has no harmful effects on enamel roughness and is an effective resource that delivered demineralization, remineralization and fluoride-uptake performance (Joiner et al., 2008). However, Yilmaz and Kanik have been reported that, human enamel brushed with distilled water creates higher surface roughness than in brushing with toothpaste containing blue covarine (Yılmaz and Kanık, 2022). In contrast to our study, they were found that silica-based blue covarine whitening toothpaste did not lead to a statistically significant increase in the level of roughness on the enamel. In our study, a decrease in surface roughness was observed in toothpaste containing blue covarine. The observed difference can be attributed to the brushing cycle, specifically noted as 30,000 brushing cycles in the study conducted by them.

The results of the study conducted by Shamel et al. (2019), which employed whitening control toothpastes and non-whitening control toothpastes, revealed no statistically significant differences in the mean values of surface roughness difference among all groups. Notably, the control group using water exhibited the least change in surface roughness, while the group with toothpaste containing blue covarine demonstrated a higher Ra value. Consistent with our in vitro study, (Colgate Optic White), containing hydrogen peroxide, showed the highest Ra value among the tested toothpastes, whereas (Colgate Total) toothpaste resulted in the smoothest surface compared to the control group. Shamel and colleagues attribute this increase in roughness to demineralization caused by hydrogen peroxide diffusion (Shamel et al., 2019).

The results of this study are consistent with our study, examined the impact of a toothpaste containing nano hydroxyapatite on subjective metrics during a four-week at home use in another observational trial. Patients in this study stated that using this toothpaste resulted in smoother and whiter teeth (Steinert et al., 2020).

Knowing the content and function of each toothpaste is helpful in choosing the most effective type (Pertiwi et al., 2017). Unfortunately, the ingredient list on toothpaste packaging usually doesn't provide specific details about the exact content of these ingredients, nor does it indicate the RDA or the relative dentin abrasivity-profilometry equivalent (RDA-PE) values (Kim et al., 2022). To address these concerns, manufacturers are continually developing new formulations of whitening toothpaste with lower abrasiveness. Some products include ingredients designed to protect and strengthen enamel while still providing whitening benefits. Therefore, it is necessary to further investigate its effect on teeth.

There are some limitations in this in vitro study. Firstly, as the teeth were randomly selected, the previous conditions such as the possible interventions were not known. Additionally, for standardization purposes, no pre-treatment was applied to the tooth surface. This approach was taken to observe its impact specifically on the tooth enamel. Another limitation of the present study is that some differences are observed between the laboratory conditions and natural atmosphere of oral cavity. It is desirable for future work, the volume loss of tooth structure prior to and following each time period was not quantified. Moreover, RDA index of the examined toothpastes should be evaluated further. Brushing technique, dietary habits, and oral hygiene habits can also impact surface morphology alterations. Therefore, a clinical study is required for further investigation. Because this was an in vitro study, the oral environment could not completely mimic the human oral cavity due to numerous factors, including the saliva factor, which naturally remineralizes the tooth surface tooth, affecting the surface hardness. Brushing technique, dietary habits, and oral hygiene habits can also impact surface morphology alterations. These aspects should be addressed in future investigations.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that whitening toothpastes tested with the brushing period affect the surface smoother of dental enamel. Toothpastes containing hydrated silica, activated charcoal, bromelain, n-HAP and blue covarine significantly reduced the surface roughness of teeth in vitro.

Although nine whitening toothpastes with different types of whitening agents were analysed, the type and size of the abrasives in the toothpastes could not be identified which could act as a confounding factor. However, since blinding was done and the methodology used was robust, the conclusions can be generalized, and it can be concluded that whitening toothpastes need to be used with caution.

Informed consent: For this type of study, formal consent is required. Informed consent was obtained from all individual participants included in the study.

Conflict of interest: The authors declare no competing interests.

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