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**ORIGINAL ARTICLE**

# Effect of bleaching agents and whitening dentifrices on the surface roughness of human teeth enamel

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**Abstract**

***Objective.*** The aim of this *in vitro* study was to evaluate the surface roughness of human enamel bleached with 10% carbamide peroxide or 10% hydrogen peroxide bleaching agents at different times and also subjected to different superficial cleaning treatments. ***Materials and methods.*** One hundred and forty flat enamel samples were divided into 14 groups, Group 1–Group 14 (G1–G14). G1–G7 were treated with 10% carbamide peroxide and different dentifrices, G8–G14 were treated with 10% hydrogen peroxide and different dentifrices (G1 and G8: not brushed as control groups; G2 and G9: brushed with Ipana® toothpaste; G3 and G10: brushed with Clinomyn® toothpaste; G4 and G11: brushed with Moos Dent® toothpaste; G5 and G12: brushed with Signal® toothpaste; G6 and G13: brushed with Colgate® toothpaste; G7 and G14: brushed without dentifrice). A profilometer was used to measure average roughness values of the initial surface roughness and at each 7-day-interval. The bleaching was performed for 6 h a day and the surface cleaning treatment was performed 3-times a day, 2 min each time, for 4 weeks. The samples were stored in distilled water during the test period. ***Results.*** Statistical analysis revealed significant differences in surface roughness values over time for all groups except G1 and G8 (not brushed). The results of the surface roughness of all groups were nearly the same. ***Conclusions.*** The bleaching with 10% hydrogen peroxide and 10% carbamide peroxide did not alter the enamel surface roughness, but when the bleaching treatment was performed combined with abrasive dentifrices, a significant increase in roughness values was observed.

**Key Words:** *bleaching, carbamide peroxide, hydrogen peroxide, surface roughness, tooth brushing*

## Introduction

Esthetical aspects are becoming increasingly important in dentistry. Bleaching procedures have gained popularity in patients and dentists to make natural teeth brighter in order to improve the harmony of the smile [1].

Dentists have tried numerous chemicals and methods to remove the various types of discoloration. Many of the earliest attempts to whiten teeth were not successful and the techniques that are used were considered to be experimental. However, dentists have been using hydrogen peroxide to bleach vital teeth for 100 years. Attempts to bleach teeth, both vital and non-vital, started in the 9th century. The innovations in esthetic dentistry led to the discovery of many techniques [2].

Dentists tried to bleach non-vital teeth in the beginning, but then they attempted to bleach vital teeth. The earliest methods for bleaching were very dangerous due to the chemicals that were used. Several oxidizing agents were used directly or indirectly to act upon the organic part of the tooth such as aluminum chloride, oxalic acid, pyrozone (either peroxide), hydrogen dioxide (hydrogen peroxide or perhydrol), sodium peroxide, sodium hypophosphate, chloride of lime and cyanide of potassium [2].

Vital whitening aims to bleach the tooth from the enamel surface and it can be performed at home [3]. Home bleaching was introduced in the 1960s. In this

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technique, 10% carbamide peroxide is commonly used [2]. Mostly 6–8 h usage during the night is stated for carbamide peroxide bleaching agents when applied at home [4].

However, application of bleaching agents like carbamide peroxide or hydrogen peroxide ($H_2O_2$) on the enamel surface has brought important questions into mind if the structure of enamel is affected in an undesirable way. Therefore, dental hard tissue which is bleached comes up in many studies with its microhardness, microstructure and content of mineral [1,5]. Previous experiments about the effects of the bleaching agents on tooth enamel surface are controversial. Because some of them indicate that no or very little change occurs in the surface roughness of the enamel after bleaching procedures, whereas some of them indicate the bleaching procedures alter the morphology of the enamel. Nevertheless, an overwhelming majority of morphological studies have been performed *in vitro*, frequently leading to different results in relation to different testing conditions, morphological aspects and the mechanical properties challenged [6].

The major differences between these studies are the type of study set up (*in vitro* or *in vivo*), sample size, type of tissue (human or bovine enamel), preparation of the tissue (polished or sound enamel), type of analysis carried out (mechanical test or morphological analysis), bleaching agent used (hydrogen peroxide or carbamide peroxide), bleaching agent concentration and formulation (gel or solution), length of bleaching agent exposure and other evaluation criteria [6].

Conversely, only a few studies have attempted to assess brushing and dentifrices effects after bleaching enamel, whereas patients commonly use them during the bleaching treatment. Some complicating factors may be explained by acknowledging that cleaning effectiveness may not be solely related to abrasion and there is concern that some abrasives may contribute to excessive tooth wear [3].

In order to have oral hygiene, powders and gels or pastes have been used for many years. The therapeutic and cosmetic endowments are obtained by dentifrices which were refined into complex formulations. Many chemotherapeutic components like antimicrobials, desensitizing agents, tartar control agents and abrasives are included by them [7]. For the cleaning process, abrasive dentifrices are significant; however, abrasiveness is not the only factor providing the effective cleaning. There are some other factors such as pyrophosphate and peroxides which are anticalculus agents providing extrinsic and intrinsic stain preventive or removal [3].

Brushing teeth every day is essential for oral health and the data collected till now is not enough to determine how the enamel surface is affected by bleaching agents when used together with tooth brushing [8]. For this reason, analysis of the enamel surface profile after use of combination bleaching agents and tooth brushing with different dentifrices *in vitro* is worthy of investigation. As currently researched, no previous studies on enamel roughness using a wide variety of cleaning agents after bleaching have been published. The aim of this *in vitro* study was to evaluate the surface roughness of human enamel bleached with 10% carbamide peroxide or 10% hydrogen peroxide bleaching agents at different times and also subjected to different superficial cleaning treatments.

## Materials and methods

For the enamel slab preparation, 140 freshly extracted human third molars were used. Subsequently, the teeth were stored in a 1% thymol solution (pH = 7). The roots were sectioned with a flexible diamond steel disk under water cooling and thrown away. Then, the crowns were longitudinally sectioned again with diamond disks (Metkon Microcut, Precision Cutter, Bursa, Turkey) under cooling and only buccal sites of the crowns were used to provide 140 slabs. After the process of cutting the teeth, they were soaked in distilled water at 37°C to protect them from room conditions and drying effects.

The enamel specimens were embedded individually in a methyl methacrylate resin block (Meliodent Self Cure Acrylic, Heraeus Kulzer Ltd., Newbury, Berkshire, UK) in a brass ring mold of 2.0 cm in diameter so that the external surface of the enamel was exposed. After separating the specimens from the ring molds, pumice powder was used to obtain smooth enamel surfaces.

The experimental units consisting of 140 sound human enamel slabs were randomly divided into 14 treatment groups, Group 1–Group 14, each group containing 10 specimens. Each group was treated with different bleaching agents or dentifrices for 4 weeks (Table I). Groups 1 and 8 were not brushed as control groups; they were only subjected to bleaching agents. Table II shows the bleaching and superficial cleaning treatments that were performed in each group.

A profilometer (Mahr Perthometer M2, Mahr GmbH, Göttingen, Germany), with a microneedle, was used to scan the specimen surfaces to determine the parameter of average surface roughness (Ra). Roughness average (Ra) is the arithmetic average of the absolute values of the roughness profile ordinates. Also known as arithmetic average (AA) or center line average (CLA). The average roughness is the area between the roughness profile and its mean line or the integral of the absolute value of the roughness profile height over the evaluation length.

All specimens were subjected to profilometric analysis to obtain the values of the initial surface roughness to determine a baseline before bleaching

Table I. Test materials used in the study.

| Treatment agents | Manufacturer | Composition |
|---|---|---|
| Carbamide peroxide | Prepared in laboratory | 10% carbamide peroxide |
| Hydrogen peroxide | Prepared in laboratory | 10% hydrogen peroxide |
| Ipana 3 Dimension Whitening | Procter & Gamble GmbH (Schwalbach, Germany) | 0.32% sodium floride, aqua, sorbitol, hydrated silica (abrasive), tetrasodium pyrophosphate, sodium lauryl sulfate, aroma, cellulose gum, Cl 77891, sodium saccharin, carbomer, trisodium phosphate, limonene, Cl 74160. |
| Clinomyn Smokers | CCS, Clean Chemical Sweden AB (Borlänge, Sweden) | 0.76% sodium monoflorofosfat, aqua, sorbitol, hydrated silica (abrasive), calcium carbonate (abrasive), aluminyum silicate (abrasive), aroma, cellulose gum, glycerine, cocamidopropyl betaine, sodium saccharin, sodium lauryl sulfate, sodium chloride, trisodium phosphate, limonene, Cl 77891, methylparaben, propylparaben. |
| Moos Dent | Moos Cosmetics (İstanbul, Turkey) | 0.15% sodium floride, calcium carbonate (abrasive), tricalcium phosphate, sodium lauryl sulfate, peppermint aroma, sodium benzoate, menthol, sodium saccharin. |
| Signal Whitening System | Unilever Mashreq – Foods & HPC Divison (Alexandria, Egypt) | Flouride (1450 ppm), perlite, calcium carbonate (abrasive), hydrated silica (abrasive), aqua, sorbitol, sodium lauryl sulfate, sodium monoflorofosfat, aroma, trisodium phosphate, cellulose gum, sodium saccharin, methylparaben, propylparaben, glycerine, Cl 77891, Cl 74160. |
| Colgate 2in1 Whitening | Colgate Palmolive (Liege, Belgium) | Sodium floride 1100 ppmF, aqua, sorbitol, hydrated silica (abrasive), sodium lauryl sulfate, glycerine, pentasodium triphosphate, tetrasodium pyrophosphate, aroma, PVM/MA copolymer, sodium saccharin, cocamidopropyl betaine, cellulose gum, sodium hydroxide, carrageenan, limonene, Cl 77891. |

treatments. Three repeated measurements of surface roughness in roughness average (Ra) values were recorded on the surface of each specimen at each 7-day interval.

For bleaching treatments two experimental bleaching agents (10% carbamide peroxide and 10% hydrogen peroxide, pH = 6.5) were prepared as solutions so that the possible differences between commercial products such as composition, density, pH and decay products could be avoided. The solution for 10% carbamide peroxide was prepared by dilution of 30% carbamide peroxide in 0.1 M phosphate buffer solution (pH = 6.5). The solution for 10% hydrogen peroxide was prepared by resolution of urea hydrogen peroxide (Sigma-Aldrich, St. Louis, MO) in 0.1 M phosphate buffer solution (pH = 6.5).

A syringe was used to apply 0.02 ml [3,8,9] of 10% carbamide peroxide solution on the enamel surface of the specimens in Groups 1–7 and 10% hydrogen peroxide solution on the enamel surface of the specimens in Groups 8–14. The bleaching was performed on the enamel surfaces for 6 h a day for a period of 28 days. After each exposure, the bleaching agent was washed out under running distilled water for 5 s. The specimens were stored in freshly prepared distilled water that was changed daily to clear the solution of the derived crumbs.

Every day, after the bleaching treatment, the specimens were submitted to a surface cleaning treatment, except Group 1 and Group 8 (control groups), according to the specification of each group, as shown in Table II A battery-powered toothbrush (Oral-B CrossAction® Power, Procter & Gamble Cincinnati, Ohio, USA) and a sort of apparatus were used for the simulated brushing procedures. The apparatus ensured applying a constant force (under a load of 200 g) on the sample surfaces by holding the toothbrush steady. The brushing was performed 3-times a day for 2 min each time in freshly prepared slurry with one part of dentifrice to three parts of deionized and distilled water. When brushing treatments were completed, the specimens were washed out with distilled water and stored in freshly prepared distilled water until the next bleaching and brushing cycle.

After brushing treatment of the test specimens following the same procedure, the roughness was evaluated again (final roughness). Data of each group were statistically analyzed by using commercial statistical software.

## Results

Although the data were quantitative, on account of time intervals and materials, the requirements of homogeneous conditions of variances couldn't have been fulfilled and a parametric statistical method was not used. Statistical analysis involved a non-parametric method using a commercial statistical software package

Table II. Bleaching agents and dentifrices used for each group.

| Group | Bleaching agent | Dentifrice |
|---|---|---|
| 1 (control group) | 10% Carbamide peroxide | not brushed |
| 2 | 10% Carbamide peroxide | Ipana 3 Dimension Whitening (Procter & Gamble GmbH, Germany) |
| 3 | 10% Carbamide peroxide | Clinomyn Smokers (CCS, Clean Chemical Sweden AB, Borlänge, Sweden) |
| 4 | 10% Carbamide peroxide | Moos Dent (Moos Cosmetics, İstanbul, Turkey) |
| 5 | 10% Carbamide peroxide | Signal Whitening System (Unilever, Egypt) |
| 6 | 10% Carbamide peroxide | Colgate 2in1 Whitening (Colgate Palmolive, Liege, Belgium) |
| 7 | 10% Carbamide peroxide | brushed without dentifrice |
| 8 (control group) | 10% Hydrogen peroxide | not brushed |
| 9 | 10% Hydrogen peroxide | Ipana 3 Dimention Whitening (Procter & Gamble GmbH, Germany) |
| 10 | 10% Hydrogen peroxide | Clinomyn Smokers (CCS, Clean Chemical Sweden AB, Borlänge, Sweden) |
| 11 | 10% Hydrogen peroxide | Moos Dent (Moos Cosmetics, İstanbul, Turkey) |
| 12 | 10% Hydrogen peroxide | Signal Whitening System (Unilever, Egypt) |
| 13 | 10% Hydrogen peroxide | Colgate 2in1 Whitening (Colgate Palmolive, Liege, Belgium) |
| 14 | 10% Hydrogen peroxide | brushed without dentifrice |

(SPSS 15.0 for Windows) and three different statistical analyses were used for this research.

Baseline data were recorded in order to verify the initial surface smoothness and compare differences between groups. Friedman test with Bonferroni correction ($p < 0.001$) was used to show the differences with time. At the baseline values and at 1, 2 and 3 weeks all groups showed statistically similar means. The groups submitted to surface cleaning treatments showed a statistically significant increase in the surface roughness with time especially at 4 weeks. However, the control groups (G1 and G8), which were not brushed, only treated with bleaching agents, presented statistically similar means of surface roughness at different time intervals (Figures 1 and 2). This means that the changes in surface roughness were due to the mechanical effect of continuous brushing.

While the first seven groups (G1–G7) were treated with 10% carbamide peroxide, the last seven groups (G8–G14) were treated with 10% hydrogen peroxide. When these two main groups were compared by using Mann Whitney test with Bonferroni correction ($p < 0.01$) the results of the surface roughness of each group were nearly the same. Table III shows the median, minimum, maximum values of surface roughness and standard deviations of the roughness parameters of each group before treatment and after each bleaching treatment at 1 week intervals for 4 weeks. Figure 3 shows statistically similar roughness values.

According to Kruskal Wallis test with Bonferroni correction ($p < 0.01$) there were statistically significant differences in groups treated with carbamide peroxide at 1, 2, 3 and 4 weeks (Table IV); also in groups treated with hydrogen peroxide at 2, 3 and 4 weeks (Table V). The control groups (G1 and G8) that were only treated with bleaching agents showed surface roughness values lower than the other groups.

## Discussion

As the popularity of the discolored teeth whitening process is increasing, patients are becoming more

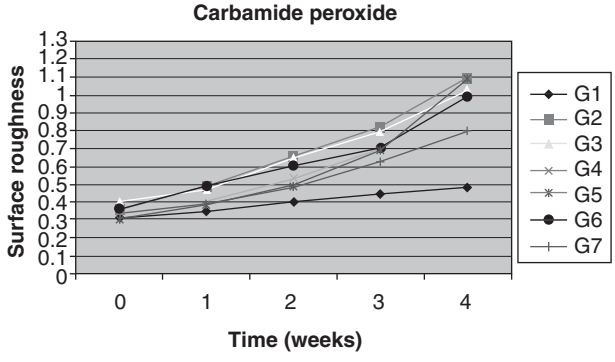


Figure 1. Mean roughness of enamel fragments bleached with carbamide peroxide and subjected to superficial cleaning treatment at different time intervals.

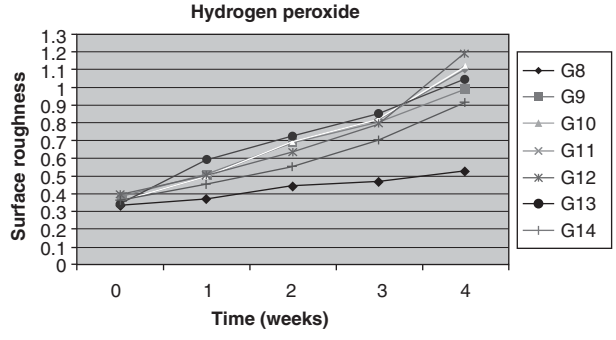


Figure 2. Mean roughness of enamel fragments bleached with hydrogen peroxide and subjected to superficial cleaning treatment at different time intervals.

Table III. Median, minimum, maximum values of surface roughness (μm) and standard deviation (SD) values for each bleaching agent, carbamide peroxide (CP) and hydrogen peroxide (HP), at different time intervals.

| Period | Bleaching agent | Median (Min–Max) | Mean ± SD | *p* |
|---|---|---|---|---|
| Baseline | CP | 0.343 (0.058–0.634) | 0.342 ± 0.099 | 0.355 |
| | HP | 0.370 (0.027–0.945) | 0.369 ± 0.159 | |
| 1 week | CP | 0.416 (0.201–0.825) | 0.423 ± 0.100 | 0.028 |
| | HP | 0.370 (0.027–0.945) | 0.369 ± 0.159 | |
| 2 weeks | CP | 0.563 (0.139–0.868) | 0.546 ± 0.146 | 0.053 |
| | HP | 0.475 (0.115–1.018) | 0.625 ± 0.210 | |
| 3 weeks | CP | 0.657 (0.118–1.175) | 0.685 ± 0.204 | 0.106 |
| | HP | 0.716 (0.335–1.604) | 0.751 ± 0.231 | |
| 4 weeks | CP | 0.906 (0.441–2.043) | 0.922 ± 0.315 | 0.282 |
| | HP | 0.954 (0.315–1.935) | 0.980 ± 0.346 | |

Mann Whitney test with Bonferroni correction compared differences between time intervals according to bleaching agent at the 1% level of significance ($p < 0.01$). No statistical difference was found between carbamide peroxide and hydrogen peroxide groups.

interested in esthetical aspects. External enamel can be treated with carbamide and hydrogen peroxide at home as vital bleaching. Or, in offices, highly concentrated bleaching agents can be used [10,11].

The objective of this study was to evaluate the surface roughness of human enamel after simulated dental bleaching and brushing *in vitro*. In the study, home bleaching procedure was simulated by using lower concentrated bleaching agents.

Nightguard vital bleaching introduced by Haywood and Heymann [12] represents an efficient and safe method that has been the most commonly used bleaching treatment in the last decades. Modification, improvements and variations of the technique, such as different concentration of carbamide peroxide agents (10–20%) with carbopol and hydrogen peroxide agents were developed [13,14]. As high concentration of hydrogen peroxide is generally used in office bleaching one advantage is faster results. Another advantage of office bleaching is that the professional has complete control over the application process [14].

The home bleaching technique, in which lower concentrations of carbamide peroxide or hydrogen peroxide are used, has the advantages of being self-administered by the patient, requiring a shorter clinical time in the dentist's chair and lower cost. However, its greatest disadvantage is the longer time required to obtain the desired results [14].

Chemical mechanism of the bleaching agents is performed by ionization of hydrogen peroxide ($2H_2O_2 \rightarrow 2H_2O + O_2$). Free oxygen ion is released during the ionization of hydrogen peroxide and that free oxygen ion oxidizes the discolored pigments on the tooth enamel. The effect mechanism of carbamide peroxide is nearly the same as hydrogen peroxide. However, urea is released during the ionization of carbamide peroxide [15–17].

The bleaching process occurs by the oxidation of the discolored pigments on tooth enamel with the chemicals in the whitening agents. During this oxidation process organic materials get harmed. Also during the application of dentifrices, oxidative whitening chemicals in the dentifrices harm the surface of the teeth in the same way [3,18]. Abrasive dentifrices might lead to a worse change of the external enamel structure when used for cleaning after bleaching process as they increase the erosion and wear effect while renewing the degraded enamel [8,19].

Patients usually want to improve their bleaching treatment by brushing their teeth 3- or 4-times a day to achieve health and beauty. For the cleaning process, abrasive dentifrices are significant within removal of extrinsic stains [7]. Throughout the bleaching process, usually patients use the abrasives dentifrices [8]. However, dentifrices are not recommended to improve bleaching process and instead they are recommended for cleaning and abrasion by removing superficial stains and polishing teeth. The bleaching agents and dentifrices combined with the

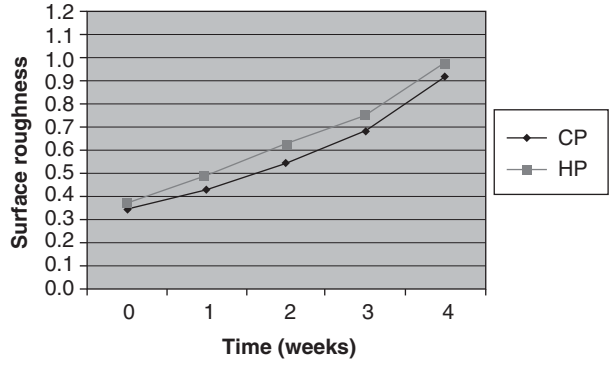


Figure 3. Mean roughness of enamel fragments treated with carbamide peroxide and hydrogen peroxide at different time intervals.

Table IV. Median, minimum, maximum values of surface roughness (μm) and standard deviation (SD) values for the groups treated with carbamide peroxide at different time intervals.

| Period | Group/ dentifrice | Median (Min–Max) | Mean ± SD | *p* |
|---|---|---|---|---|
| Baseline | G1/ not brushed | 0.314 (0.261–0.362) | 0.315 ± 0.034 | 0.045 |
| | G2/ Ipana | 0.372 (0.297–0.392) | 0.356 ± 0.032 | |
| | G3/ Clinomyn | 0.404 (0.241–0.528) | 0.402 ± 0.074 | |
| | G4/ Moos Dent | 0.314 (0.261–0.387) | 0.316 ± 0.041 | |
| | G5/ Signal | 0.314 (0.058–0.602) | 0.308 ± 0.154 | |
| | G6/ Colgate | 0.340 (0.123–0.634) | 0.361 ± 0.147 | |
| | G7/ no dentifrice | 0.380 (0.167–0.521) | 0.337 ± 0.113 | |
| 1 week | G1/ not brushed | 0.348 (0.293–0.398) | 0.347 ± 0.033 | 0.000 |
| | G2/ Ipana | 0.483 (0.437–0.528) | 0.480 ± 0.030 | |
| | G3/ Clinomyn | 0.475 (0.382–0.591) | 0.474 ± 0.058 | |
| | G4/ Moos Dent | 0.389 (0.358–0.446) | 0.397 ± 0.032 | |
| | G5/ Signal | 0.402 (0.265–0.525) | 0.384 ± 0.097 | |
| | G6/ Colgate | 0.451 (0.201–0.825) | 0.492 ± 0.192 | |
| | G7/ no dentifrice | 0.392 (0.316–0.463) | 0.390 ± 0.047 | |
| 2 weeks | G1/ not brushed | 0.403 (0.358–0.446) | 0.402 ± 0.030 | 0.000 |
| | G2/ Ipana | 0.645 (0.598–0.728) | 0.653 ± 0.046 | |
| | G3/ Clinomyn | 0.654 (0.489–0.728) | 0.649 ± 0.068 | |
| | G4/ Moos Dent | 0.530 (0.415–0.719) | 0.538 ± 0.095 | |
| | G5/ Signal | 0.487 (0.139–0.812) | 0.491 ± 0.225 | |
| | G6/ Colgate | 0.614 (0.394–0.868) | 0.606 ± 0.140 | |
| | G7/ no dentifrice | 0.453 (0.335–0.743) | 0.484 ± 0.131 | |
| 3 weeks | G1/ not brushed | 0.449 (0.395–0.480) | 0.446 ± 0.025 | 0.000 |
| | G2/ Ipana | 0.846 (0.608–1.002) | 0.821 ± 0.125 | |
| | G3/ Clinomyn | 0.818 (0.587–0.977) | 0.797 ± 0.111 | |
| | G4/ Moos Dent | 0.685 (0.564–0.901) | 0.710 ± 0.132 | |
| | G5/ Signal | 0.668 (0.118–1.175) | 0.692 ± 0.289 | |
| | G6/ Colgate | 0.641 (0.342–1.116) | 0.704 ± 0.282 | |
| | G7/ no dentifrice | 0.650 (0.472–0.733) | 0.625 ± 0.083 | |
| 4 weeks | G1/ not brushed | 0.488 (0.441–0.506) | 0.484 ± 0.019 | 0.000 |
| | G2/ Ipana | 0.983 (0.817–2.043) | 1.096 ± 0.356 | |
| | G3/ Clinomyn | 0.942 (0.723–1.903) | 1.027 ± 0.337 | |
| | G4/ Moos Dent | 0.942 (0.723–1.503) | 0.972 ± 0.218 | |
| | G5/ Signal | 1.063 (0.819–1.472) | 1.091 ± 0.214 | |
| | G6/ Colgate | 0.860 (0.725–1.647) | 0.990 ± 0.310 | |
| | G7/ no dentifrice | 0.774 (0.627–1.078) | 0.795 ± 0.128 | |

Kruskal Wallis test with Bonferroni correction ($p < 0.01$) showed that significant differences were found at 2, 3 and 4 weeks in carbamide peroxide groups.

brushing process can cause abrasions on the teeth enamel [3,19]. The use of a bleaching agent before brushing with dentifrice could be a determining factor for the alterations on the enamel surface [18].

Previous experiments about the effects of the bleaching agents on tooth enamel surface are controversial. Some of them indicate that no or very little change occurs in the surface roughness of the enamel after bleaching procedures, whereas some of them indicate the bleaching procedures alter the morphology of the enamel. According to the results of a study the sole use of bleaching agents didn't change the surface roughness of the human teeth enamel; however, brushing created significant abrasive effects [3]. On the other hand, according to the results of other studies bleaching agents didn't cause significant changes on enamel. Instead it was suggested that the cause for the abrasion could be due to the pH

levels of the bleaching agents [11,20,21]. The acidity might be the most likely reason for the negative effects of bleaching agents with lower pH value. Neutral bleaching agents could be recommended to tooth bleaching for the purpose of reducing deleterious effects on tooth enamel [11].

A similar experiment also exhibited similar results as this study. It was indicated that bleaching alone, bleaching and brushing and water soaking had no measurable effect on enamel and specimens remained within baseline acceptance values, within and between these groups analyses showed no significant differences. It was indicated that no significant changes occurred on the surface roughness of the samples after bleaching with 35% hydrogen peroxide [20]. However, another study showed that 35% hydrogen peroxide increased the surface roughness of dental enamel [16].

In this study, although the specimens were not stored in a remineralization solution, instead they were stored in distilled water, the control groups G1 and G8, which were only treated with bleaching agents, did not show a significant increase in surface roughness. The studies in which remineralization solutions with Calcium and Phosphate in concentrations similar to natural saliva were used for storage of the specimens presented no statistical increase in surface roughness, similar to this study [3,8]. The use of artificial saliva may decrease superficial erosion and it might favor remineralization of the enamel surface, a possible reason for the results of some studies [1,3,8,9]. However, in a study in which distilled water was used for storage of the specimens, 10% carbamide peroxide treatment did not alter the enamel surface, like in this study [22]. An *in vivo* study, in which the bleaching treatment was performed with a rubber dam and no contact with saliva was allowed, showed no alterations on enamel surfaces. It is indicated that the absence of morphological and profilometric changes on the enamel surface after bleaching treatments might be due to the relatively neutral pH of the tested products (carbamide peroxide and hydrogen peroxide, pH = 6.5), well above the critical for enamel demineralization. The critical pH for enamel is ~ 5.5 [9].

The aim of this study was to evaluate *in vitro* the effect of 10% carbamide peroxide and 10% hydrogen peroxide bleaching agents associated to abrasive dentifrices brushing. G1 and G8 may be considered as control groups because they were not brushed, only treated with bleaching agents (G1 treated with 10% carbamide peroxide, G8 treated with 10% hydrogen peroxide) and they did not present alterations in surface roughness during the experimental treatment times. G7 and G14 were second control groups whose specimens were brushed without dentifrices and treated with bleaching agents (G7 treated with 10% carbamide peroxide, G14 treated with 10% hydrogen peroxide) and they showed a significant increase in roughness values. This suggests that the most important factor for the change in surface roughness of the enamel is the mechanical brushing with or without dentifrice not the bleaching agents. According to the explanation of chemical mechanism of the bleaching agents, releasing the free oxygen ions can cause damage on the enamel surface by affecting the organic materials and also brushing with or without dentifrices increases this depredation by increasing the erosion and wear effect.

Abrasives are the insoluble components added to toothpaste in order to aid the physical removal stains, plaque and food debris. In contemporary dentifrices, the abrasives used include hydrated silica, calcium carbonate, dicalcium phosphate dihydrate, calcium pyrophosphate, alumina, perlite and sodium bicarbonate. There are a number of key parameters that have been demonstrated to affect the abrasive cleaning process, including particle hardness, shape, size, size distribution, concentration and applied load. Their abrasive effects may cause superficial tooth wear and other complicating factors and abrasion may become more severe when associated to bleaching treatments [7,23].

The enamel surface roughness was increased after the surface cleaning treatments with abrasive dentifrices in G2–G6 and G9–G13. Although the roughness of these groups had been similar during all experiment times, the increase occurred from the 21$^{st}$ day for all groups. The dentifrices used in this study were similar to each other, they had a whitening system and they were fluoridated. It is expected that abrasive contents were also similar, thus their surface roughness values showed no statistically significant increase. Whitening dentifrices produce higher surface roughness in the composites, too. The degree of surface compromising increases with brushing time and depends on the composites' microstructure and composition [23].

According to a similar study, the use of fluoridated dentifrice was not able to prevent the increase in surface roughness [8,24]; while another study indicated that topical fluoride therapies were effective at reducing the increase in enamel surface roughness after bleaching [16].

The contact time with enamel and concentration of the bleaching agents are also important for the alterations on the enamel surface. Thirty-eight per cent hydrogen peroxide and 35% carbamide peroxide are the highest concentrated bleaching products commercially available [10,25]. High concentrations of hydrogen peroxide (35%) [26] and carbamide peroxide (35%) [27] showed significantly higher values of surface roughness. However, it was indicated that the appropriate use of high concentration bleaching products had no effect on the surface roughness of enamel [10,28]. The use of 10% carbamide peroxide and 10% hydrogen peroxide did not

Table V. Median, minimum, maximum values of surface roughness (μm) and standard deviation (SD) values for the groups treated with hydrogen peroxide at different time intervals.

| Period | Group/ dentifrice | Median (Min–Max) | Mean ± SD | *p* |
|---|---|---|---|---|
| Baseline | G8/ not brushed | 0.356 (0.217–0.404) | 0.331 ± 0.071 | 0.833 |
| | G9/ Ipana | 0.376 (0.178–0.634) | 0.384 ± 0.148 | |
| | G10/ Clinomyn | 0.378 (0.163–0.554) | 0.353 ± 0.136 | |
| | G11/ Moos Dent | 0.358 (0.238–0.597) | 0.417 ± 0.114 | |
| | G12/ Signal | 0.363 (0.192–0.683) | 0.401 ± 0.172 | |
| | G13/ Colgate | 0.319 (0.124–0.542) | 0.341 ± 0.164 | |
| | G14/ no dentifrice | 0.310 (0.027–0.945) | 0.362 ± 0.269 | |
| 1 week | G8/ not brushed | 0.366 (0.335–0.421) | 0.374 ± 0.031 | 0.120 |
| | G9/ Ipana | 0.478 (0.268–0.743) | 0.502 ± 0.163 | |
| | G10/ Clinomyn | 0.500 (0.115–0.918) | 0.497 ± 0.234 | |
| | G11/ Moos Dent | 0.489 (0.394–0.651) | 0.495 ± 0.069 | |
| | G12/ Signal | 0.525 (0.217–0.749) | 0.506 ± 0.164 | |
| | G13/ Colgate | 0.597 (0.294–0.865) | 0.592 ± 0.208 | |
| | G14/ no dentifrice | 0.373 (0.213–1.018) | 0.452 ± 0.245 | |
| 2 weeks | G8/ not brushed | 0.444 (0.343–0.558) | 0.442 ± 0.066 | 0.001 |
| | G9/ Ipana | 0.737 (0.526–0.885) | 0.696 ± 0.124 | |
| | G10/ Clinomyn | 0.588 (0.455–1.443) | 0.700 ± 0.294 | |
| | G11/ Moos Dent | 0.624 (0.518–0.741) | 0.620 ± 0.081 | |
| | G12/ Signal | 0.573 (0.401–0.952) | 0.637 ± 0.185 | |
| | G13/ Colgate | 0.740 (0.367–1.096) | 0.726 ± 0.212 | |
| | G14/ no dentifrice | 0.460 (0.319–1.281) | 0.551 ± 0.285 | |
| 3 weeks | G8/ not brushed | 0.454 (0.421–0.562) | 0.468 ± 0.047 | 0.000 |
| | G9/ Ipana | 0.865 (0.607–0.942) | 0.802 ± 0.136 | |
| | G10/ Clinomyn | 0.742 (0.619–1.604) | 0.822 ± 0.287 | |
| | G11/ Moos Dent | 0.717 (0.648–1.257) | 0.818 ± 0.231 | |
| | G12/ Signal | 0.767 (0.507–1.162) | 0.790 ± 0.220 | |
| | G13/ Colgate | 0.911 (0.523–1.087) | 0.853 ± 0.171 | |
| | G14/ no dentifrice | 0.716 (0.335–1.173) | 0.705 ± 0.236 | |
| 4 weeks | G8/ not brushed | 0.500 (0.430–0.678) | 0.522 ± 0.091 | 0.000 |
| | G9/ Ipana | 0.905 (0.704–1.593) | 0.986 ± 0.297 | |
| | G10/ Clinomyn | 0.978 (0.735–1.851) | 1.118 ± 0.350 | |
| | G11/ Moos Dent | 0.991 (0.638–1.935) | 1.083 ± 0.370 | |
| | G12/ Signal | 1.148 (0.729–1.704) | 1.193 ± 0.319 | |
| | G13/ Colgate | 0.980 (0.761–1.439) | 1.046 ± 0.211 | |
| | G14/ no dentifrice | 0.984 (0.315–1.344) | 0.912 ± 0.302 | |

Kruskal Wallis test with Bonferroni correction ($p < 0.01$) showed that significant differences were found at 2, 3 and 4 weeks in hydrogen peroxide groups.

increase the surface roughness like presented in other studies [3,8,29]. However, the results of another study suggested that bleaching agents containing 10% carbamide peroxide and 7.5% hydrogen peroxide may lead to micro-alterations in the surface micromorphology of enamel with an application protocol of 1 h a day for 21 days [13].

In this study only one parameter, surface roughness, was evaluated. Although it is the most used parameter to evaluate roughness, other parameters like microhardness and scanning electron microscope (SEM) photomicrographs may be helpful to cross-check the data about the profile shape.

Many surface measurement applications use a profilometer. The profilometer's stylus tip is dragged across the sample much as a phonograph needle might move across a record on a turntable; changes in *Z* (the axis that measures height) are registered and

noted. Surface profiling equipment is relatively affordable and can be used with a wide variety of surface types. Indeed, these instruments have provided an established and accepted method to measure surface roughness [9].

One key disadvantage of surface profilometers is that they touch the surface they are measuring, which can lead to contamination, damage or destruction of the part. In addition, they are slow, as they have to probe each location along an axis and then move, meaning one measurement in one axis at a time. Collecting plane roughness data can be a challenge and it can be complex and time-consuming. In addition, fixing the position of the sample can be difficult when the operator is working in a small or narrow area. Finally, surface profilometers cannot be used for any device that is beyond the reach of the probe. Narrow, deep channels can be impossible to measure accurately. Nevertheless, the profilometer is a useful instrument because it is pervasive and relatively inexpensive and offers higher lateral resolution than most other techniques [7].

There are few studies which evaluate the effects of home bleaching agents when they are used with abrasive dentifrices on enamel roughness. Further *in vitro* and *in vivo* studies are necessary to assess the adverse effects in terms of other aspects on the enamel surface.

Within the limitations of this *in vitro* study, it was concluded that bleaching with 10% hydrogen peroxide and 10% carbamide peroxide did not alter the enamel surface roughness, but when the bleaching treatment was performed combined with abrasive dentifrices, a significant increase in roughness values was observed.

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## References

[1] Wiegand A, Otto YA, Attin T. *In vitro* evaluation of toothbrushing abrasion of differently bleached bovine enamel. Am J Dent 2004;17:412–16.

[2] Greenwall L. Bleaching techniques in restorative dentistry: an illustrated. guide. London: Martin Dunitz Ltd; 2001.

[3] Worschech CC, Rodrigues JA, Martins LR, Ambrosano GM. Brushing effect of abrasive dentifrices during at-home bleaching with 10% carbamide peroxide on enamel surface roughness. J Contemp Dent Pract 2006;7:1–9.

[4] Llambés G, Llena C, Amengual J, Forner L. *In vitro* evaluation of the efficacy of two bleaching procedures. Med Oral Patol Oral Cir Bucal 2011;16:e845–51.

[5] Magalhães JG, Marimoto AR, Torres CR, Pagani C, Teixeira SC, Barcellos DC. Microhardness change of enamel due to bleaching with in-office bleaching gels of different acidity. Acta Odontol Scand 2012;70:122–6.

[6] Cadenaro M, Breschi L, Nucci C, Antoniolli F, Visintini E, Prati C, et al. Effect of two in-office whitening agents on the enamel surface *in vivo*: a morphological and non-contact profilometric study. Oper Dent 2008;33:127–34.

[7] Joiner A. Whitening toothpastes: a review of the literature. J Dent 2010;38(Suppl 2):e17–24.

[8] Worschech CC, Rodrigues JA, Martins LR, Ambrosano GM. *In vitro* evaluation of human dental enamel surface roughness bleached with 35% carbamide peroxide and submitted to abrasive dentifrice brushing. Braz Oral Res 2003;17:342–8.

[9] Faraoni-Romano JJ, Silveira AG, Turssi CP, Serra MC. Bleaching agents with varying concentrations of carbamide and/or hydrogen peroxides: effects on dental microhardness and roughness. J Esthet Restor Dent 2008;20:395–404.

[10] Sulieman M, Addy M, Macdonald E, Rees JS. A safety study *in vitro* for the effects of an in-office bleaching system on the integrity of enamel and dentine. J Dent 2004;32:581–90.

[11] Sun L, Liang S, Sa Y, Wang Z, Ma X, Jiang T, et al. Surface alteration of human tooth enamel subjected to acidic and neutral 30% hydrogen peroxide. J Dent 2011;39:686–92.

[12] Haywood VB, Heymann HO. Nightguard vital bleaching. Quintessence Int 1989;20:173–6.

[13] Sasaki RT, Arcanjo AJ, Flório FM, Basting RT. Micromorphology and microhardness of enamel after treatment with home-use bleaching agents containing 10% carbamide peroxide and 7.5% hydrogen peroxide. J Appl Oral Sci 2009;17:611–16.

[14] Batista GR, Barcellos DC, Torres CR, Goto EH, Pucci CR, Borges AB. The influence of chemical activation on tooth bleaching using 10% carbamide peroxide. Oper Dent 2011;36:162–8.

[15] Dias Ribeiro AP, Sacono NT, Lessa FC, Nogueira I, Coldebella CR, Hebling J, et al. Cytotoxic effect of a 35% hydrogen peroxide bleaching gel on odontoblast-like MDPC-23 cells. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:458–64.

[16] Martin JM, de Almeida JB, Rosa EA, Soares P, Torno V, Rached RN, et al. Effect of fluoride therapies on the surface roughness of human enamel exposed to bleaching agents. Quintessence Int 2010;41:71–8.

[17] Cakir FY, Korkmaz Y, Firat E, Oztas SS, Gurgan S. Chemical analysis of enamel and dentin following the application of three different at-home bleaching systems. Oper Dent 2011;36:529–36.

[18] Hilgenberg SP, Pinto SC, Farago PV, Santos FA, Wambier DS. Physical-chemical characteristics of whitening toothpaste and evaluation of its effects on enamel roughness. Braz Oral Res 2011;25:288–94.

[19] Navimipour EJ, Kimyai S, Nikazar S, Ghojazadeh M. *In vitro* evaluation of the effect of delaying toothbrushing with toothpaste on enamel microhardness subsequent to bleaching the teeth with 15% carbamide peroxide. Oper Dent 2012;37:87–92.

[20] Moraes RR, Marimon JLM, Schneider LFJ, Correr Sobrinho L, Camacho GB, Bueno M. Carbamide peroxide bleaching agents: effects on surface roughness of enamel, composite and porcelain. Clin Oral Investig 2006;10:23–8.

[21] Xu B, Li Q, Wang Y. Effects of pH values of hydrogen peroxide bleaching agents on enamel surface properties. Oper Dent 2011;36:554–62.

[22] Pinto CF, Oliveira R, Cavalli V, Giannini M. Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology. Braz Oral Res 2004;18:306–31.

[23] Barbieri GM, Mota EG, Rodrigues-Junior SA, Burnett LH Jr. Effect of whitening dentifrices on the surface roughness of commercial composites. J Esthet Restor Dent 2011;23:338–45.

[24] Altenburger MJ, Bernhart J, Schicha TD, Wrbas KT, Hellwig E. Comparison of *in vitro* fluoride uptake from whitening toothpastes and a conventional toothpaste in

demineralised enamel. Schweiz Monatsschr Zahnmed 2010; 120:104–13.

[25] Reis A, Tay LY, Herrera DR, Kossatz S, Loguercio AD. Clinical effects of prolonged application time of an in-office bleaching gel. Oper Dent 2011;36:590–6.

[26] Cavalli V, Arrais CAG, Giannini M, Ambrosano GMB. High-concentrated carbamide peroxide bleaching agents effects on enamel surface. J Oral Rehabil 2004;31:155–9.

[27] Cobankara FK, Unlü N, Altinöz HC, Füsun O. Effect of home bleaching agents on the roughness and surface morphology of human enamel and dentine. Int Denl J 2004;54:211–18.

[28] Azrak B, Callaway A, Kurth P, Willershausen B. Influence of bleaching agents on surface roughness of sound or eroded dental enamel specimens. J Esthet Restor Dent 2010;22: 391–9.

[29] Faraoni-Romano JJ, Turssi CP, Serra MC. Concentration-dependent effect of bleaching agents on microhardness and roughness of enamel and dentin. Am J Dent 2007;20: 31–4.