Effects of different concentrations of carbamide peroxide and bleaching periods on the roughness of dental ceramics

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Abstract: The wide use of dental bleaching treatment has brought concern about the possible effects of hydrogen peroxide on dental tissue and restorative materials. The objective of this study was to evaluate *in vitro* the effect of nightguard bleaching on the surface roughness of dental ceramics after different periods of bleaching treatment. Fifteen specimens of 5 × 3 × 1 mm were created with three dental ceramics following the manufacturers' instructions: IPS Classic (Ivoclar-Vivadent); IPS d.Sign (Ivoclar-Vivadent); and VMK-95 (Vita). A profilometer was used to evaluate baseline surface roughness (Ra values) of all ceramics by five parallel measurements with five 0.25 mm cut off (λc) at 0.1 mm/s. Afterwards, all specimens were submitted to 6-h daily bleaching treatments with 10% or 16% carbamide peroxide (Whiteness- FGM) for 21 days, while control groups from each ceramic system were stored in artificial saliva. The surface roughness of all groups was evaluated after 18 h, 42 h, 84 h, and 126 h of bleaching treatment. The surface roughness of each specimen (n = 5) was based on the mean value of five parallel measurements in each time and all data were submitted to two-way repeated measures ANOVA and Tukey's post-hoc test (α = 0.05). No significant differences in ceramic surface roughness were observed between untreated and bleached ceramic surfaces, regardless of bleaching intervals or bleaching treatments. This study provided evidence that at-home bleaching systems do not cause detrimental effects on surface roughness of dental ceramics.

Descriptors: Esthetics, Dental; Tooth Bleaching; Hydrogen Peroxide; Surface Properties; Ceramics.

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Introduction

In recent years, dental bleaching has become popular and often requested by patients wanting to improve their teeth shade. The most useful and effective bleaching technique is the one performed at home, in which bleaching of all the teeth is undertaken over two weeks, with few side effects such as dental sensitivity.[1] This technique was firstly described by Haywood & Heymann in 1989 as nightguard dental bleaching, but today this technique may be performed at home from one to eight hours a day, involving the day or nighttime use of a tray with a bleaching agent.[1,2]

The most commonly used dental bleaching agent is carbamide per-

oxide. The reaction of carbamide peroxide with the teeth releases hydrogen peroxide and free radicals, which are responsible for dental bleaching.[3,4] Despite the wide approval of at-home bleaching techniques, the use of peroxides may lead to clinical side effects due to the reactive nature of hydrogen peroxide, so patients may experience dentin sensitivity and/or gingival irritation.[1,3-5] Several microscopic changes on the enamel surface morphology are also observed, due to enamel mineral loss and surface roughening.[6-15]

Extremely unstable and reactive H^+ free radicals, released by bleaching agents, and low pH are described as the main cause of the side effects of prolonged use of these products.[6-14,16-17] Similarly, bleaching agents may cause structural changes on restorative materials that may compromise their physical properties and lead to premature failure.[18-24] Although conventional dental ceramics are considered the most inert among all dental restorative materials, their surfaces can exhibit surface deterioration in contact with acidulated fluoride gels or other solutions.[25] In addition, the contact and possible diffusion of free radicals of H^+ or H_3O^+ produced by bleaching agents[17] may selectively leach alkali ions and cause dissolution in ceramic glass networks.[25] Thus, prolonged exposure to hydrogen peroxide through at-home bleaching treatment may potentially affect dental porcelain and may produce alterations on the porcelain's surface.[16] Moreover, an increase in surface roughness greater than the threshold of Ra = 0.2 μm may result in an increase in plaque accumulation, thereby increasing the risk of both secondary caries and periodontal inflammation[26] or affecting ceramic aesthetics by changing the ceramic texture.[16]

The aim of the present study was to evaluate the effect of 10% and 16% carbamide peroxide nightguard bleaching agents on the surface roughness of dental ceramics after different time periods of bleaching treatment. Thus, the hypothesis of the present study was that the surface roughness of ceramic might be modified by exposure to 10% and 16% carbamide peroxide bleaching agents used in at-home treatment for a period of 126 h.

Methodology

The surface roughness of three dental ceramics (Table 1) – one fluorapatite glass-ceramic, IPS d.Sign (Ivoclar Vivadent AG - Schaan, Liechtenstein), and two feldspathic ceramics, IPS Classic (Ivoclar Vivadent AG - Schaan, Liechtenstein), and VMK 95 (Vita Zahnfabrik - Bad Säckingen, Germany) – were evaluated in a research protocol, including a factorial design to test the effects of three surface treatments: 10% carbamide peroxide (Whiteness FGM, Joinville, Brazil; pH ≅ 6.0); 16% carbamide peroxide (Whiteness FGM, Joinville, Brazil; pH ≅ 6.0); and no treatment (control group); at five periods of treatment: 0 h (baseline), 18 h, 42 h, 84 h, and 126 h.

Fifteen specimens with 5 × 3 × 1 mm of each ceramic were prepared according to the manufacturers' instructions and their surfaces were sequentially

Table 1 - Ceramic materials used in this study: commercial brand, lot, type, and chemical characterization*.

Ceramic (Lot number)	Type	Chemical characterization*
IPS d.Sign (Lot: K33292)	Fluorapatite-leucite glass-ceramic	SiO_2; BaO; Al_2O_3; CaO; CeO_2; Na_2O; K_2O; B_2O_3; MgO; ZrO_2; P_2O_5; F; Li_2O; TiO_2; SrO; ZnO; and pigments
VMK 95 (Lot: 26590)	Feldspathic ceramic	Al_2O_3; BaO; B_2O_3; CaO; Fe_2O_3; MgO; SiO_2; TiO_2; ZrO_2; CeO_2; Li_2O; K_2O; Na_2O; glycerin; butylene glycol; tin oxide
IPS Classic (Lot: K02827)	Feldspathic ceramic	SiO_2; BaO; Al_2O_3; CaO; CeO_2; Na_2O; K_2O; B_2O_3; MgO; ZrO_2; P_2O_5; TiO_2; and pigments

* Material Safety Data Sheet; Abbreviations: SiO_2: Silicon Oxide; BaO: Barium Oxide; Al_2O_3: Aluminum Oxide; CaO: Calcium Oxide; CeO_2: Cerium Dioxide; Na_2O: Sodium Oxide; K_2O: Potassium Oxide; B_2O_3: Boron Oxide; MgO: Magnesium Oxide; ZrO_2: Zirconium Oxide; P_2O_5: Phosphorus Pentoxide; F: Fluorine; Li_2O: Lithium Oxide; TiO_2: Titanium Dioxide; SrO: Strontium Oxide; ZnO: Zinc Oxide; Fe_2O_3: Iron Oxide.

polished with diamond polishing pastes of 6, 3, 1, and 0.5 μm and polishing cloths with mineral oil lubricant (Top, Gold and Ram, Arotec Ind. Com. Ltda., Cotia, Brazil).

Surface roughness was evaluated by a single blinded evaluator prior to and after all bleaching periods. A profilometer (TR200, Time Group Inc., Beijing, China), with a microneedle, was used to scan the specimen surfaces to determine the parameter of average surface roughness (Ra). Five points were initially marked to ensure repeatable measurements. From these points, five parallel measurements in a longitudinal direction were performed on each specimen surface, with a 0.25 mm cut off (λc) at 0.1 mm/s. Surface roughness was recorded, and mean roughness (Ra expressed in μm) was determined for each specimen before and after each treatment period.

Fifteen ceramic specimens were randomly divided into three groups according to surface treatments (n = 5). The respective treatment agent was applied for six hours a day over 21 days, corresponding to 126 hours of treatment. Specimens to be bleached were covered with 0.03 ml of the respective bleaching agent, were placed in vacuum-formed custom trays with a drop of artificial saliva,[8,13] and were stored in a plastic container at 37 °C.[6-8] Specimens from control groups were stored only with artificial saliva drops in the vacuum-formed custom tray to mimic oral conditions.

After bleaching exposure, specimens were washed with distilled water to remove residual carbamide peroxide gel and were stored in a plastic container for the remaining day period in relative humidity at 37 °C.

Surface roughness was measured at 18 h, 42 h, 84 h, and 126 h after the beginning of the experiment, after the specimens were washed and dried. Data of each ceramic material were statistically analyzed by two-way repeated measures ANOVA and Tukey's post-hoc test at a 5 % level of significance within each period, using statistical software (SAS 8.0 for Windows; SAS Institute Inc., Cary, USA).

Results

Mean Ra values of each ceramic material before and after treatment, with the respective standard deviations, are shown in Table 2. No significant differences in Ra values were observed between the control group and bleached groups, as well as between groups treated with 10% carbamide peroxide and those treated with 16% carbamide peroxide, regardless of time. Moreover, no significant differences in Ra were observed among time intervals, regardless of treatment. Figure 1 shows the surface roughness of each ceramic treated with 10% or 16% carbamide peroxide as a function of time.

Discussion

Ceramics are expected to be chemically stable in the mouth, as dental prostheses must withstand degradation in the presence of a wide range of solutions

Table 2 - Surface roughness (Ra) of each ceramic and standard deviation (SD) at each evaluation period.

Ceramic	Surface treatment	0 h	18 h	42 h	84 h	126 h
IPS d.Sign	Control	0.035 ± 0.001	0.037 ± 0.002	0.036 ± 0.003	0.033 ± 0.004	0.036 ± 0.002
	CP 10%	0.036 ± 0.003	0.033 ± 0.002	0.035 ± 0.002	0.033 ± 0.002	0.034 ± 0.003
	CP 16%	0.031 ± 0.002	0.033 ± 0.003	0.034 ± 0.004	0.033 ± 0.001	0.032 ± 0.004
VMK 95	Control	0.073 ± 0.002	0.070 ± 0.004	0.074 ± 0.002	0.074 ± 0.002	0.073 ± 0.003
	CP 10%	0.074 ± 0.003	0.075 ± 0.004	0.073 ± 0.003	0.074 ± 0.003	0.074 ± 0.003
	CP 16%	0.074 ± 0.003	0.072 ± 0.004	0.072 ± 0.003	0.074 ± 0.005	0.074 ± 0.002
IPS Classic	Control	0.075 ± 0.002	0.077 ± 0.002	0.076 ± 0.001	0.076 ± 0.002	0.075 ± 0.002
	CP 10%	0.075 ± 0.004	0.078 ± 0.004	0.077 ± 0.003	0.076 ± 0.004	0.076 ± 0.003
	CP 16%	0.080 ± 0.004	0.0786 ± 0.004	0.077 ± 0.002	0.079 ± 0.003	0.080 ± 0.002

No significant difference in surface roughness was noted among the groups or treatment periods ($p > 0.05$); CP: carbamide peroxide.

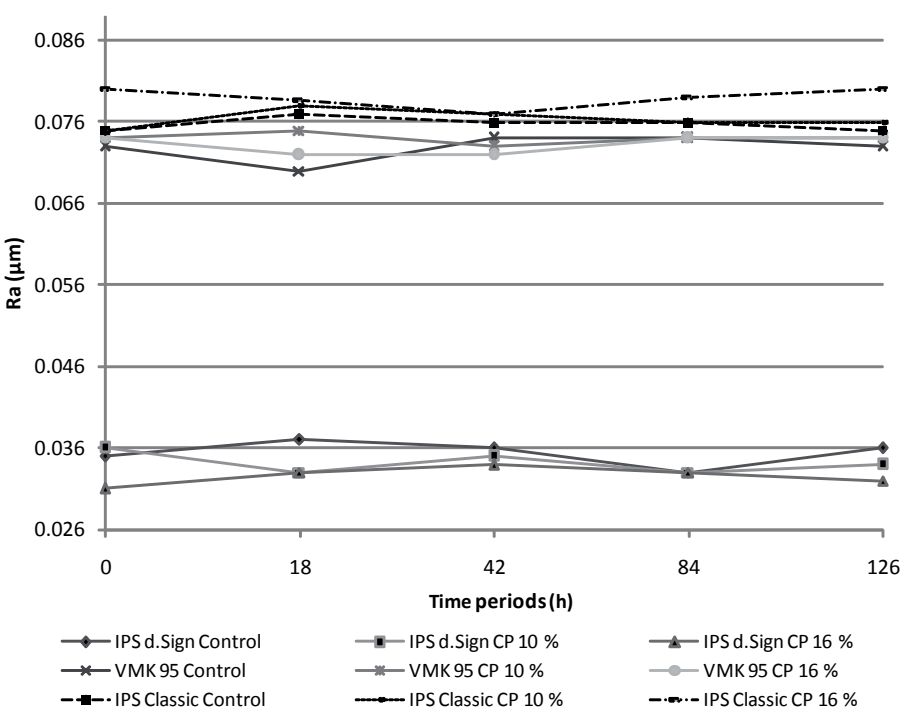

Figure 1 - Mean surface roughness (Ra) of each ceramic as a function of time.

with variable pH levels.[25] Otherwise, ceramics could release potentially toxic substances and radioactive components and exhibit increased wear, abrasion of opposing dental structures, and increased plaque adhesion after exposure to such intra-oral challenges.[25]

This study tested the effects of dental bleaching agents on the surface roughness of ceramic specimens with standardized initial roughness averages less than 0.2 µm, a condition that leads to bacterial accumulation similar to that observed on the least rough surface.[26] Therefore, any possible change in roughness due to *in vitro* treatment would be detected by contact profilometry.[11,12,16,26] No significant differences in ceramic roughness were observed after 126 hours of exposure to 10% or 16% carbamide peroxide in comparison to the baseline values, demonstrating that all products were inert *in vitro* to dental bleaching, so the hypothesis of this study was rejected. Our results corroborate those of Zavanelli *et al.*,[27] who found no alterations on ceramic surfaces treated with 10% or 15% carbamide peroxide for 126 h. Therefore, accidental exposure of dental ceramics to bleaching agents does not change their surface roughness to values capable of increasing the risk for both secondary caries and periodontal inflammation.

The bleaching protocol used in this study was similar to that used in other studies, which aimed to evaluate *in vitro* the effect of bleaching systems on enamel surface roughness over time.[6,8,9,13] Although an increase in roughness has been observed in composite resins or glass ionomers after bleaching treatment,[18-24,27] no alteration in ceramic surfaces was observed after bleaching in the current study,[23] so the impact of bleaching agents on surface roughness may be considered material-dependent, as also demonstrated by previous studies.[16,20-23] In these studies, the chemical stability of ceramics against bleaching agents was observed after treatment with 15% carbamide peroxide for 56 h,[23] 16% carbamide peroxide for 126 h,[17] 10% or 15% carbamide peroxide[27] and 38% hydrogen peroxide for 30 minutes[23] or 45 minutes, respectively.[24]

The 126-hour bleaching protocol was chosen to simulate 21-day nightguard bleaching treatment, as most patients achieve the best results within this period.[4,5] Although this period may be considered optimal, bleaching treatment may be extended to longer treatment periods in patients with severe dis-

coloration. As the detrimental effects of bleaching treatment are time-dependent, more mineral loss is expected on enamel and dentin surfaces in extended treatments.[1,6,24] Therefore, despite the lack of changes in ceramic surface roughness from the beginning throughout 126 h of bleaching treatment, it is possible that overexposure to bleaching agents for longer than 126 h might lead to some degradation in ceramics due to the interaction between free radicals released from the bleaching gels and the ceramic glass network, which leads to the loss of alkali metal ions from the glass surface. However, only further evaluation, comprising longer exposure to bleaching agents, would confirm such speculation. Thus, a time-dependent effect of bleaching treatment on ceramic roughness should not be discarded because only one study observed a statistically significant decrease in auto-glazed ceramic roughness after treatment with 35% and 15% carbamide peroxide for 56 h followed by acid fluoride gel treatment for 30 h, which was probably due to a mild etching of the ceramic caused by a carbamide peroxide agent with the additive effect of fluoride gel.[16] Furthermore, an energy-dispersive x-ray microanalysis of ceramic surfaces exhibited a decrease in SiO_2 content, which is the main matrix component.[21] Thus, its lower content would affect other properties, such as surface microhardness, although the study found no significant difference in roughness. In addition, Polydorou *et al.* (2006)[24] showed that the effect of bleaching on surface texture was material- and time-dependent, as polished ceramic surfaces exposed to 38% hydrogen peroxide for 45 minutes showed slight changes in surface texture evaluated by scanning electron microscopy, while no significant difference was noted when ceramic surfaces were exposed to 15% carbamide peroxide for 56 h.[26]

However, other authors have demonstrated that bleaching gels affected the surface roughness of dental ceramics. A statistically significant increase occurred in the surface roughness of ceramic material after 21 days of daily application of 10% carbamide peroxide and a weekly application of 35%, although no alterations in roughness were observed over seven and 14 days of bleaching. According to the authors, these results were related to the leaching of components from the porcelain matrix as a function of continuing peroxide application. However, all Ra values were within the clinically acceptable range (Ra values of 0.22 to 0.24), and the changes would most likely be clinically insignificant. In addition, scanning electron microscopy analyses showed surface changes on ceramic surfaces after bleaching treatment, but the authors described them as clinically insignificant.[28-30]

The degradation of dental ceramics generally occurs because of chemical attacks, mechanical forces or a combination of these effects.[25] In the current study, only a chemical attack of ceramics by 10% or 16% hydrogen peroxide was considered, but different results might be found if mechanical forces were applied because they could weaken the structure by creating surface cracks and increasing ceramic susceptibility to sequential bleaching attacks. For this reason, further studies are required to evaluate this clinical challenge.

In this regard, the present study showed that ceramic dental materials were not affected by 10% or 16% carbamide peroxide treatment, so there is no need for ceramic polishing or replacement in clinical situations in which ceramic restorations are accidentally exposed to bleaching gels, provided that shade, shape, and function are clinically acceptable.

Conclusion

Within the study limitations, the surface roughness of all evaluated dental ceramics was not affected by treatment with 10% or 16% carbamide peroxide for 126 hours.

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