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Original Article

Effects of repeated home bleaching on the surface roughness of CAD-CAM restoration materials

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Abstract

Aim: This study aimed to investigate the effects of the repeated usage of a home-bleaching agent (16% carbamide peroxide) on the surface roughness of commonly used computer-aided design-computer-aided manufacture (CAD-CAM) restoration materials.

Methodology: Five different CAD-CAM restoration materials were used in this study: feldspathic ceramic (Vita Mark II—Group VM II), leucite-reinforced glass ceramic (IPS Empress CAD—Group EMP), lithium disilicate-reinforced glass ceramic (IPS e.max CAD—Group EMAX), polymer infiltrated network hybrid ceramic (Vita Enamic—Group VE), and resin nanoceramic (Lava Ultimate—Group LU). A home-bleaching agent containing 16% carbamide peroxide was applied in three repeated periods (10 days, 20 days, and 30 days of exposure). A surface profilometer was used to determine the roughness average (Ra) values of the specimens. The data obtained were statistically analyzed using repeated measures of the analysis of variance (ANOVA) and Bonferroni post-hoc test at a 5% level of significance.

Results: All materials exhibited a rougher surface after the first treatment period (10 days of exposure). The roughness of Group VM II continued to increase for up to 20 days. With the exception of Group LU, all groups exhibited a significantly rougher surface after 30 days of exposure compared to the baseline values ($p < 0.05$). The greatest variation in surface roughness was observed for the ceramic-based groups (VM II, EMP, and EMAX) rather than the hybrid groups (LU and VE).

Conclusion: Patients with ceramic-based CAD-CAM restorations should be careful during home-bleaching treatment, especially when repeated applications are involved. Hybrid materials, particularly Lava Ultimate, seem more resistant to the effects of repeated bleaching cycles than ceramic-based materials.

Keywords: Home beaching, surface roughness, CAD-CAM, feldspathic ceramic, reinforced glass ceramic, resin nano ceramic

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Introduction

In this rapidly changing and developing world, the concept of esthetics is also changing, and patients' expectations are increasing steadily. Dental bleaching has become more popular in recent years, with an increasing number of patients demanding it in clinical settings. The most useful, as well as effective, whitening technique is home bleaching (1). In present-day pandemic conditions in particular, this technique has become patients' preferred method. The home-bleaching technique, which was first described as the nightguard bleaching technique in 1989, has evolved into the use of a bleaching material with a special tray over a period ranging from 1 to 8 hours a day (2, 3). The most widely used bleaching material for this technique is carbamide peroxide (CP) (4). The bleaching effect of CP arises from the active oxygen radicals released by it (4, 5). While home bleaching has been widely approved by clinicians, the hydrogen peroxide contained in bleaching materials can cause clinical outcomes such as dentin hypersensitivity and gingival irritation (5, 6). Furthermore, it is stated in the literature that microscopic changes are observed in the surface morphology of the enamel, depending on mineral loss. Bleaching agents can also cause physical and structural changes in the restoration materials used, leading to early failure (5–7). Surface roughness is one of the most important factors in dental restorations; it affects several clinical features, such as the longevity of the restoration, its esthetic appearance, and plaque retention (8). An increase in roughness greater than 0.2 µm (the threshold Ra value for dental materials) can increase the risk of periodontal inflammation by increasing plaque deposition; it may also alter the surface texture of the material and affect the restoration shade (9, 10). While dental ceramics are generally considered to be inert materials, their surfaces may exhibit surface degradation upon contact with H+ or peroxide free radicals (11, 12). Therefore, prolonged exposure to hydrogen peroxide can cause changes in the porcelain (9).

In recent times, interest in computer-aided design-computer-aided manufacture (CAD-CAM) restorations that can be performed chairside has increased. Consequently, ceramic- and hybrid-based CAD-CAM restoration materials with different chemical contents and properties have been developed, and their use has become widespread. A few previous studies (13, 14) have evaluated the effects of office bleaching on ceramic- and hybrid-based materials; however, studies on the effects of home bleaching on these materials remain limited, despite home-bleaching applications presenting more potential risks than office-bleaching applications due to the likelihood of uncontrolled usage by patients.

The present study aimed to evaluate the effects of the repeated usage of a home-bleaching agent (16% carbamide peroxide) on the surface roughness of widely used CAD-CAM restoration materials. The null hypothesis of this study was that repeated periods of usage would not cause changes in the surface roughness of the materials.

Materials and Methods

In this study, a home-bleaching agent containing 16% carbamide peroxide (Whiteness Perfect, FGM, Joinville, SC, Brazil) was used. Fifty specimens were prepared using esthetic CAD-CAM materials, namely three different ceramic-based and two different hybrid-based materials (n=10). The experimental groups, the materials used, the materials' contents, and the materials' manufacturers are listed in Table 1.

To ensure standardization, monochromatic blocks with the same shade and translucency (2M1/HT for Group VM II, A2/HT for Group EMAX, A2/HT for Group EMP, 2M1/HT for Group VE, and A2/HT for Group LU) were used in all materials. All blocks were cut into 2-mm slices using a precision cutting machine (IsoMet 1000 Low Speed Saw, Buehler, Illinois, USA) with a diamond cutting disk (Isomet Diamond Wafering Blades 127 × 0.4 mm, Buehler, Illinois, USA). Each specimen surface was polished with coarse to fine grid disks (Shofu Super-Snap Rainbow Technique kit, Kyoto, Japan) and 0.5-µm polishing pastes (Ultradent Diamond, Ultradent, Utah, USA). The bleaching agent was applied on the specimens' surfaces for 4 hours a day according to the manufacturer's instructions over a period of 10 days (first application period), 20 days (second application period), and 30 days (third application period). Following the exposure process, the specimens were washed to remove the remaining gel and stored in distilled water in a closed container for the remaining days. A contact profilometer (Mitutoyo Surftest SJ-310, Japan) was used to determine the surface roughness values. Five parallel measurements were performed on the specimens in the same regions (previously marked), with a 0.25 mm cut-off at 0.1 mm/s. The mean roughness average values (Ra) were recorded for each specimen.

Statistical analysis

The data obtained were statistically analyzed using SPSS statistical software (IBM SPSS v26.0, IBM Corp., Armonk, New York, USA). Normality of the experimental data obtained from each group were explored for using Shapiro-Wilk test. In order to determine the effects of repeated usage of bleaching on roughness in different exposure times, Repeated Measures ANOVA test was used. Differences between groups were evaluated with post-hoc Bonferroni test at a 5% level of significance.

Results

Table 2 summarizes the mean surface roughness values and standard deviations of all the material groups at baseline, 10 (first period), 20 (second period), and 30 days of exposure (third period) tested with the 16% carbamide peroxide home bleaching agent. Figure 1 shows a graphical illustration of changes in mean roughness values of restoration materials after repeated treatment versus the exposure time.

Table 1. Experimental groups and CAD-CAM materials used in the study.

Groups	Material	Brand Name/Manufacturer	Chemical composition
VM II	Feldspathic ceramic	Vita Mark II, Vita Zahnfabrik, Bad Säckingen, Germany	SiO_2, Al_2O_3, Na_2O, K_2O
EMP	Leucite reinforced glass ceramic	IPS Empress CAD. Ivoclar Vivadent, Schaan, Liechtenstein	Leucite crystals, SiO_2, Al_2O_3, K_2O, Na_2O, other oxides and pigments
EMAX	Lithium disilicate reinforced glass ceramic	IPS e.max CAD. Ivoclar Vivadent, Schaan, Liechtenstein	Lithium disilicate crystals, SiO_2, Li_2O, K_2O, P_2O_5, ZrO_2, ZnO
VE	Polymer-infiltrated ceramic network	Vita Enamic/ Vita Zahnfabric, Bad Sackingen, Germany	Ceramic part: SiO_2, Al_2O_3, Na_2O, K_2O, B_2O_3, < 1% ZrO_2 and KaO. Polymer part: UDMA, TEGDMA
LU	Resin nano ceramic	Lava Ultimate/3M Espe, Seefeld, Germany	80% nanoceramic particles (20 nm Silica, 4-11 nm Zirconia and zirconia/silica combined nanoparticles), bound in the highly cross-linked polymeric resin matrix.

The results from repeated ANOVA measurements revealed that the type of restoration material and exposure time of the bleaching agent significantly affect surface roughness (p < 0.001). The surface roughness values of hybrid material groups (VE and LU) were greater than those of reinforced ceramic materials (groups EMP and EMAX) at the baseline, and these values were similar (p = 0.418). Groups EMP and EMAX were similar, with mean roughness values less than that of the VM II feldspathic ceramic group (p = 0.013 and p < 0.001, respectively). All materials exhibited a significantly rougher surface after the first period of the home bleaching treatment (10 days of exposure, p < 0.05). Roughness of groups LU and VE did not change significantly under subsequent exposure times. Nevertheless, the roughness of group VM II increased up to 20 days, with no statistical differences between the 20th and 30th days of exposure. Group EMAX exhibited significantly increased roughness during the second period of treatment. No statistical difference was observed between the 20th and 30th days of exposure for group EMAX. Group EMP exhibited similar roughness values between the 10th and 20th days of exposure. However, the third period of treatment (i.e., 30 days of exposure) led to a significant roughening effect on the surface of group EMP. All materials, except LU, exhibited a significantly rougher surface after 30 days of exposure compared to the baseline values (p < 0.05). The highest change in the surface roughness after 10 days was observed for groups EMAX and EMP, after 20 days was observed for groups EMAX and VM II, and after 30 days was observed for groups EMAX, EMP, and VM II.

Table 2. Mean surface roughness values and standard deviations up to 30 days of exposure (Ra, µm)

Groups	Material	n	Baseline	10 days (First period)	20 days (Second period)	30 days (Third period)
VM II	Feldspathic ceramic	10	0.09 (0.02)^{A,a}	0.14 (0.02)^{B,a}	0.22 (0.04)^{C,a}	0.25 (0.03)^{C,a}
EMP	Leucite reinforced ceramic	10	0.04 (0.01)^{A,b}	0.08 (0.02)^{B,b}	0.09 (0.03)^{B,b}	0.17 (0.04)^{C,ab}
EMAX	Lithium disilicate reinforced ceramic	10	0.03 (0.01)^{A,b}	0.06 (0.01)^{B,b}	0.18 (0.02)^{C,ac}	0.20 (0.03)^{C,ab}
VE	Polymer infiltrated ceramic	10	0.14 (0.01)^{A,c}	0.19 (0.01)^{B,c}	0.20 (0.02)^{B,a}	0.20 (0.02)^{B,a}
LU	Resin nanoceramic	10	0.12 (0.02)^{A,ac}	0.17 (0.04)^{B,ac}	0.14 (0.03)^{AB,c}	0.14 (0.02)^{AB,b}

* Different capital letters in a line differ in exposure time. Different small letters in a column differ in materials (Bonferroni test, 5% significance level)

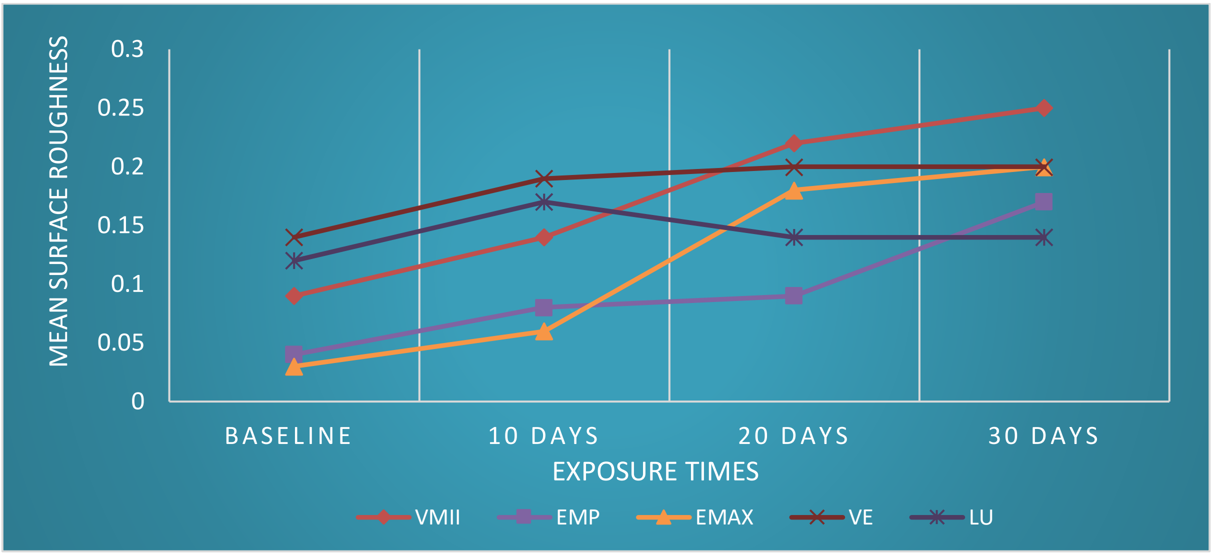

Figure 1. Graphical presentation of the changes in mean surface roughness values of CAD-CAM restoration materials depending repeated treatment exposure times of the home bleaching treatment. VM II: Vita mark II, EMP: IPS Empress CAD, EMAX: IPS e.max CAD, VE: Vita Enamic, LU: Lava Ultimate

Discussion

In this study, the effect of the repeated use of a home bleaching agent on the surface roughness of commonly used CAD-CAM restoration materials was investigated. According to our results, the 16% concentrated carbamide peroxide bleaching agent, which is the most commonly preferred concentration for home bleaching applications, affected the roughness of the materials. The null hypothesis that repeated home bleaching would not change the surface roughness of CAD-CAM materials was rejected.

Previous studies reported that home bleaching products can affect the enamel surface (15, 16). However, marginal information regarding the effect of bleaching applications and repeated use on CAD-CAM materials is available. Different structural and chemical contents of CAD-CAM materials can lead to different interactions between the bleaching agent and material's surface. A recent study (17) evaluated the effect of 16% CP on the roughness and hardness of glazed leucite and lithium disilicate-reinforced CAD-CAM materials (IPS Empress CAD and IPS e.max CAD, respectively). The authors reported that the surface roughness of both materials is significantly increased after 7 days (17). Rangel et al. (13) evaluated the roughness of ceramic and hybrid CAD-CAM materials after exposure to office bleaching agents (35% CP) for 15 min in three sessions and reported similar roughness values after treatment. Although high-concentration agents are used for office bleaching, the exposure time is shorter than that used for home bleaching applications. Some studies reported that exposure to low-concentration CP agents does not cause surface alteration (18, 19). However, an extended exposure time, even if low concentrations are used, can lead to surface deterioration. Moraes et al. (19) reported that CP affects the surface roughness of feldspathic ceramic after an exposure time of 21 days. Similarly, Butler et al. (20) reported that CP bleaching might exhibit significant roughening effects on porcelain. Our results revealed that group VM II feldspathic porcelain exhibits a significantly rougher surface after an exposure time of up to 20 days. This result may be related to the leaching of various components from the porcelain matrix due to repetitive peroxide application. El-Murr et al. (21) reported that bleaching application leads to the reduction in the number of silicon dioxide ($SiO2$) and potassium peroxide ($K2O2$) molecules from the porcelain surface, affecting roughness. A previous surface analysis reported that that the $SiO2$ content of feldspathic porcelain is reduced to 4.82% after exposure to the 10% CP home bleaching agent (22). In our studies, the use of the 16% carbamide peroxide bleaching agent caused significant changes in the surface roughness of ceramic-based materials, corresponding to VM II, EMP, and Emax groups. These findings may be related to the reduction in the number of $SiO2$ molecules.

Studies on the effects of bleaching on Emax are limited. A current study (23) reported that after 1-h office bleaching (35% CP), the surface roughness of Emax press is higher. The authors stated that bleaching should not be preferred for IPS e.max Press to prevent changes in roughness. According to Bollen et al. (10), the surface roughness values of dental materials should be less than 0.2 µm to minimize the bacterial retention amount. In our study, the baseline roughness values of polished material groups were less than 0.2 µm. However, after exposure to the bleaching agent, the mean roughness of VM II ceramic exceeded the threshold roughness values at an exposure time of 20 days. After 30 days of exposure, only group LU exhibited a roughness significantly less than 0.2 µm. Based on these results, home bleaching can be used safely for CAD-CAM materials up to 10 days. However, repeated applications can lead to a surface with higher roughness, making restoration susceptible to plaque deposits. Only Lava Ultimate material can be used safely up to an exposure time of 30 days to 16% CP.

According to Karakaya and Cengiz-Yanardag (24), CP home bleaching did not exert a roughening effect on LU and VE materials. However, according to our results, both materials exhibited statistically significant, but clinically unsignificant (<0.2 µm), rougher surfaces after the first period of bleaching (10 days of exposure). Different results from the previous study might be related to the lower baseline roughness of the specimens and use of dependent groups in our study. Although the initial roughness values in both hybrid groups were greater than those in ceramic-based groups, the amount of roughness change at the end of 30 days was considerably less than that of ceramic-based materials. In repeated periods (after 20 and 30 days of exposure), LU and VE did not exhibit significantly increased roughness values. At the end of 30 days, Ra value of LU was less than that of VE. One of the reasons for this result may be that the filler particle size of LU is less than that of VE. In addition, a highly cross-linked polymer matrix structure and zirconia-based nanoparticles of LU may be lead to a more resistant surface than feldspathic ceramic of VE after use by the bleaching agent (24).

Conclusions

This study questioned the potential effects of home bleaching on the surface roughness of CAD-CAM restoration materials, especially after repeated applications. Although real effects depend on various conditions, repeated home bleaching treatments have different effects on the surface and depend on the materials. Patients who have ceramic-based CAD-CAM restorations should be careful during home bleaching treatment, especially in repeated applications. Hybrid materials, especially Lava Ultimate, were more resistant to roughening effect of bleaching periods than ceramic-based CAD-CAM materials.

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