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FULL PAPER

Effect of different bleaching procedures on hardness and surface roughness of nanohybrid composite restorations

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The survival of composite restorations largely hinges on two critical factors: surface roughness and microhardness. This study aimed to evaluate the individual and combined effects of home and office bleaching methods on these parameters in nanohybrid composite restorations. In this *in vitro* experimental study, 56 disc-shaped composite specimens (6 mm diameter and 3 mm thickness) were used. Following polishing, they were randomly assigned into four groups (n=14 each): (I) control (immersed in distilled water), (II) home bleaching with 22% carbamide peroxide (CP), (III) office bleaching with 35% hydrogen peroxide (HP), and (IV) a combination of office and home bleaching. Vickers hardness testing and surface roughness measurements using a profilometer were performed. To determine the differences among the study groups, a one-way analysis of variance (ANOVA) was employed, followed by the Bonferroni test for post-hoc pairwise comparisons, and statistical significance was considered at a p-value <0.05. Group IV exhibited a significant reduction in microhardness compared to the control group (P-value: 0.05). Furthermore, the surface roughness in Group IV was notably higher than both the control and Group II (p-value= 0.05). The study concludes that while individual home or office bleaching techniques do not significantly impact the surface hardness or roughness of composite materials, their combined application results in significant reductions in microhardness and increases in surface roughness. These findings underscore the need for careful consideration of bleaching techniques in dental practice, especially for patients with composite restorations.

KEYWORDS

Office bleaching; home bleaching; microhardness; surface roughness .

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Introduction

Facial attractiveness highly depends on a beautiful and harmonic smile, and is an important factor in social interactions. Tooth color and gingival show are also among the main factors implicated in a beautiful smile [1]

.Several factors can affect smile design including the position, shape and form, and color of teeth [2].

Composite restorations are more favored by most dental clinicians and patients due to higher esthetics and more conservativeness compared with amalgam restorations [3].

However, surface roughness of composite restorations affects their durability and esthetics [4].

Rough surfaces are unaesthetic and enhance discoloration, biofilm accumulation, and food and plaque retention, which can subsequently lead to development of secondary caries and gingivitis, and increase the risk of periodontal disease and cause wear of the opposing teeth. Evidence shows that bacterial accumulation directly depends on surface roughness [5].

Surface hardness of composite resins is another important property which depends on degree of polymerization of composite resin, and has an important role in resistance of composite against wear by the opposing teeth or restorations [5-6].

Tooth bleaching is a highly demanded esthetic treatment due to its fast results and not requiring tooth preparation and removal of tooth structure to whiten the tooth shade or correct the discolorations [7].

Bleaching treatment is an effective method for correction of discolorations and should be considered as the first esthetic procedure to perform [8-9].Bleaching of vital and non-vital teeth has a long history of success [5].

Evidence shows that bleaching is relatively safe in terms of possible changes in tooth structure. Nonetheless, some concerns still exist regarding the adverse effects of bleaching agents on restorative materials. Surface hardness and roughness parameters are commonly evaluated to assess the possible adverse effects of bleaching on restorative materials. The effects of bleaching on resin-based materials depend on the type of resin, composition of bleaching gel, and duration and frequency of exposure [7].

The results regarding the effects of bleaching gel on surface hardness of composite resins have been controversial [10].

For instance, de Andrade *et al.* [11].reported that bleaching decreased the surface hardness of composite while Polydrou *et al.* [12] reported no adverse effect of bleaching on surface hardness of composite resin. According to Aristole University research, the surface hardness and surface roughness of composites does not change due to high concentration bleaching materials [4].

Concerning the importance of the mentioned cases and the contradictions witnessed in previous studies, and the scarce investigation of the effect of the combined home and office bleaching on a composite sample in previous studies, the aim of this research is to explore the aforementioned effect on the surface properties of composite restorations. Accordingly, our study employs an experimental design, examining the impact of both home and office bleaching treatments on the hardness and surface roughness of nanohybrid composite restorations, providing a comprehensive analysis of their combined effects.

Materials and methods

This *in vitro*, experimental study was conducted on 56 cylindrical specimens with 6 mm diameter and 3 mm thickness fabricated from Charisma nano-hybrid composite (Kulzer, Germany). The current study was conducted according to the Declaration of Helsinki and approved by the Medical Ethical Committee of Arak University of Medical Sciences (IR.ARAKMU.REC.1399.229).

The patients signed informed consent forms prior to participation in the study. The authors certify that the study was performed in accordance with relevant guidelines and regulations. For the fabrication of composite specimens, a cylindrical acrylic mold was used. The mold was filled with composite, a polyester band and a glass slab were placed over it, and compressed with 500 g load for 30 seconds in order for the excess material to leak out and obtain a smooth surface parallel to the ground. After removal of glass slab, the specimens were cured with a curing unit (Woodpecker, China) with a light intensity of 1200 mW/cm^2 for 20 seconds. The light intensity was periodically checked by a radiometer. The specimens were removed from the mold and immersed in distilled water at 37 °C for 24 hours. Next, the specimens were polished with coarse, medium, fine, and ultrafine aluminum discs (3M ESPE, St. Paul, MN, USA). In this study, only cylindrical specimens with a 6 mm diameter and 3 mm thickness, composed of Charisma nanohybrid composite, were included. Specimens were excluded if they deviated from the prescribed size, material composition, or failed to undergo the specified preparation, curing, polishing, and bleaching protocols. This ensured consistency in quality and comparability across all test groups.

Bleaching process

56 specimens were randomly divided into four groups (n=14) as follows: Group 1 served as the control group and underwent no bleaching process. The specimens in this group were immersed in distilled water for 14 days. In group 2, home bleaching was performed using Whiteness Perfect (FGM, Brazil) containing 22% carbamide peroxide (CP) as instructed by the manufacturer. Therefore, gel was gently applied on the surface of specimens for 2 hours a day for 14 days. The gel was then removed by a soft toothbrush from the surface of specimens and they were rinsed with water twice. Group 3 specimens were subjected to office bleaching using whiteness hydrogen peroxide (HP) Maxx (FGM, Brazil) containing 35% HP according to the manufacturer's instructions. Accordingly, gel was applied in 0.5 to 1 mm thickness on the surface of specimens and subjected to light and heat as instructed by the manufacturer. It was allowed to remain on the surface for 20 minutes after each time of application. Next, it was removed from the surface of specimens by a surgical suction. This process was repeated three times to obtain the desired results. Next, the gel was completely wiped off from the surface of specimens and they were rinsed with air and water spray. In group 4, office bleaching was initially performed as explained for group 3, and then home bleaching was performed as explained for group 2. The primary variables investigated in this study were the Vickers hardness and surface roughness of the composite specimens.

Surface hardness

To measure the surface hardness, the specimens in all groups underwent Vickers hardness test in Innova testing machine (Europe BV, 423, the Netherlands). The device was calibrated according to the manufacturer's instructions. The Vickers hardness test was performed by applying 200 g load for 20 seconds. Each measurement was repeated 3 times at random sites on each specimen surface, and the mean value was calculated and reported as the Vickers hardness number.

Surface roughness

Surface roughness of specimens was measured by a profilometer (SURFSCAN 200; Moore & Wright, UK). The device was calibrated as instructed by the manufacturer. Three sites were assessed on each specimen surface, and the mean value in micrometers (μm) was calculated and reported. For the purpose of standardization, the center point of each specimen along with two other points with 2 mm distance from the center point was assessed for surface roughness.

Statistical analysis

The sample size was calculated to be 14 in each group according to a previous study [13]. Assuming 95% confidence interval, and 90% study power using STATA 11 software. The normality of data distribution was evaluated by the Kolmogorov-Smirnov test, which confirmed the normality of the distribution of data. Thus, the significance of differences among the study groups, a one-way analysis of variance (ANOVA) was employed, followed by the Bonferroni test for post-hoc pairwise comparisons. All statistical analyses were performed using STATA 11 software, and statistical significance was considered as a p-value < 0.05.

Results

A significant finding from our study is the distinct effect of combined home and office bleaching procedures on the microhardness of composite materials (Table 1).

Specifically, Group 4, which underwent both office and home bleaching, exhibited a notable decrease in microhardness, registering a mean Vickers hardness number of 49.02±2.1. This value was significantly lower than that of the control group, which had a mean hardness of 51.61±2.02 (P-value: 0.035).

Further, pairwise comparisons using Tukey's test, as presented in Table 2, reinforce the unique impact of the combined bleaching treatment on surface hardness, distinguishing it from the effects observed in the other groups.

TABLE 1 Mean surface hardness of the four groups

Group	Mean ±std.
Control	51.61±2.02
Home bleaching	50.45±1.96
Office bleaching	49.69±3.35
Office + home bleaching	49.02±2.1
P-value	0.044

TABLE 2 Pairwise comparisons of the groups regarding surface hardness by Tukey test

Group	Mean difference	P-value
Control Home bleaching	1.16	0.596
Control Office bleaching	1.92	0.174
Control Office + Home bleaching	2.59	0.035
Home bleaching Office bleaching	0.76	0.843
Home bleaching Office + Home bleaching	1.43	0.418
Office bleaching Office + Home bleaching	0.67	0.887

TABLE 3 Mean surface roughness (µm) of the four groups

Group	Mean and std. deviation
Control	0.55±0.08
Home bleaching	0.58±0.14
Office bleaching	0.65±0.16
Office + home bleaching	0.72±0.13
P-value	0.007

TABLE 4 Pairwise comparisons of the groups regarding the surface roughness (µm) by Tukey test

Group	Mean difference	*P*-value
Control Home bleaching	- 0.3	0.938
Control Office bleaching	-1.02	0.212
Control Office + Home bleaching	-1.73	0.008
Home bleaching Office bleaching	-0.72	0.510
Home bleaching Office + Home bleaching	-1.43	0.038
Office Bleaching Office + Home bleaching	-0.71	0.518

The study also revealed a significant alteration in surface roughness, particularly in specimens subjected to both office and home bleaching methods. The average surface roughness in Group 4 was measured at 0.72±0.13 µm, which was markedly higher than that of the control group (0.55±0.08 µm) and the home bleaching group (0.58±0.14 µm), with p-values of 0.008 and 0.038, respectively. These comparisons, detailed in Table 3, highlight the considerable effect of combined bleaching treatments on surface roughness. Additional comparative insights are provided in Table 4, delineating the differential effects of the various bleaching procedures on this parameter. The average surface roughness between groups “Control” and “Office + Home bleaching” and groups “Home bleaching” and “Office + Home bleaching” was significantly different in a way that the average surface roughness in group 4 is higher than in groups 1 and 2. In contrast, difference among other groups recorded no statistical significance.

Discussion

The principal finding of our study is the significant impact of combined home and office bleaching procedures on the microhardness and surface roughness of nanohybrid composite restorations. This distinct effect underscores the cumulative impact of these bleaching methods when used in conjunction, a phenomenon is not observed when either method is applied independently.

Surface hardness

Our findings resonate with the work of Fernandes *et al.* [16]. and Polydorou *et al.* [19] who observed negligible changes in surface hardness with individual bleaching treatments. This consistency across studies suggests that the reaction of composite materials to bleaching agents hinges substantially on the nature, agents' concentration, and the specific methods of their application. However, the notable decrease in surface hardness and increase in surface roughness in our study, particularly under combined bleaching conditions, marks a distinct departure from these earlier observations. This divergence highlights the nuanced and potentially more complex interactions between composite materials and bleaching agents when used in a sequential or combined manner.

Contrastingly, our results differ from those reported by Yikilgan I *et al.* [18].and Wongpraparatana *et al.* [20].who documented significant changes in composite properties following different bleaching regimens. The variance can be attributed to the differing concentrations of bleaching agents, the duration of exposure, and the types of composites used, underscoring the multifaceted nature of these interactions. Notably, our study extends the existing body of knowledge by exploring the combined effects of home and office bleaching on composites, an aspect scarcely addressed in previous research. In the study by Mourouzis P *et al.* in 2013, they investigated the effect of office bleaching agents on the physical properties of three types of composite restorative materials. The samples surface was measured before and after the application of bleaching materials. The results were that the surface roughness and surface hardness of Siluran-based composite resin do not change due to bleaching, which is in line with our study [4].

In the study by Polydorou *et al.* in 2007, they investigated the effect of 15% CP bleaching on the surface hardness of 6 cosmetic restorative materials. They concluded that home bleaching with 15% CP produced no significant change in surface hardness of composite materials, which is consistent with our study [19].

In our study, group 4, which initially underwent office bleaching and then home bleaching, showed a significant decrease in surface hardness compared to the control group. In the studies that have been done so far, the effect of combined office and home bleaching on the composite sample has not yet been investigated. On one hand, the result obtained from group four in this study can be justified as bleaching in the office and bleaching at home cannot cause a significant reduction in surface hardness by them. On the other hand, when both are used together, they can reduce the surface hardness of composite samples. It is plausible that this result was derived due to the composite material being in contact with the bleaching material for a longer time.

Surface roughness

The increase in surface roughness following combined bleaching treatments, as seen in our study, contrasts with the findings of Bahari *et al.* [5].and Rodrigues *et al.* [21]. where individual bleaching treatments did not significantly alter surface roughness. This contrast points towards a potentially synergistic effect of using home and office bleaching techniques in tandem, emphasizing the need for further exploration into the interplay of these methods.

In the context of dental practice, these insights are crucial. The cumulative effect of different bleaching procedures on composite restorations necessitates careful consideration of treatment plans, particularly for patients with existing composite restorations. Understanding the combined impact of various bleaching techniques is vital to preserve the integrity and aesthetics of dental composites. Moreover, in this study, we concluded that in group 4, the surface roughness of composite resins increases significantly compared to the control group, and also compared to the group that only underwent home bleaching. Although no study has been performed investigating this effect, the results obtained from this study can be justified by suggesting that performing only one of the methods of home bleaching or office bleaching cannot cause a significant increase in the surface roughness of composites. In contrast, when they are used together, they can cause a significant increase in surface roughness.

Also, the surface roughness created after office bleaching and home bleaching are not significantly different from each other. In other words, only applying office bleaching cannot increase the surface roughness in composites compared to home bleaching. In contrast, when both office bleaching and home bleaching are applied to composite samples, the surface roughness of these composites increases significantly compared to the surface roughness of composites that have only been affected by home bleaching. Therefore, it is suggested that dentists, when performing such treatment for patients, take the necessary measures to avoid contact between the bleaching material and the composite restorations in the patient's mouth.

This study, while providing valuable insights into the effects of bleaching treatments on nanohybrid composite restorations, does possess certain limitations that must be acknowledged. Primarily, the *in vitro* nature of our experimental design limits the direct extrapolation of our findings to clinical scenarios. The laboratory setting, although meticulously controlled, does not fully replicate the complexities of the oral environment, including factors like saliva, temperature fluctuations, and mechanical stresses. In addition, the study exclusively used one type of composite material, which may not represent the wide range of materials used in clinical practice. Furthermore, the long-term effects of bleaching treatments on composite materials were not explored, as our study was limited to immediate post-treatment assessments. Recognizing these constraints is crucial for contextualizing our findings and provides a basis for future research to extend this study, potentially including a broader range of materials and conditions that more closely mimic the clinical setting.

Conclusion

The findings of our study provide a nuanced understanding of the impact of bleaching treatments on composite dental restorations. Our research indicates that individual home or office bleaching procedures do not significantly alter the surface hardness or roughness of nanohybrid composite restorations. However, a noteworthy observation from our study is the significant change in both surface hardness and roughness when a combination of home and office bleaching methods is applied. These changes were notably more pronounced compared to the control group and the group subjected only to home bleaching. This underscores the importance of careful consideration in clinical practice, particularly regarding the combined use of different bleaching techniques on patients with composite restorations. Our study highlights the need for dental practitioners to be mindful of the potential cumulative effects of bleaching treatments to ensure the longevity and aesthetic integrity of composite restorations. Future research in this area should aim to explore these effects over longer periods and across a wider range of composite materials to further our understanding of the optimal use of bleaching treatments in dental care.

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Study design: MSh, AN, HS, and VT. Data collection and analysis: MSh, AN, and HS. Manuscript preparation: MSh, AN, and HS.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest in this work.

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