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Influence of dental bleaching on the microhardness and flexural strength of resin composites

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ABSTRACT

Purpose. This study aimed to examine the influence of dental bleaching systems (home bleaching system and two in-office bleaching systems) on the surface microhardness, and flexural strength of the two resin composite restorative materials (Beautifil II and OliREVO).

Methods. For each test, a total of 48 samples were prepared with both types of composites. The samples of each type of composite were divided at random into four groups each of six samples, control group (C) was not bleached and kept in distilled water, other three groups (G1, G2, and G3) were bleached with 10% hydrogen peroxide (HP) home beaching, 35% and 40% HP in-office bleaching systems, respectively. To measure the composite resin's microhardness, a Vickers microhardness tester was used, while a universal testing machine was used to measure its flexural strength.

Results. For statistical analysis, Duncan and ANOVA tests were used. A *p*-value ≤ 0.01 indicates statistically significant results. In- office bleaching systems (35% and 40% HP) significantly reduced microhardness and flexural strength of the used resin composites. Generally, the hardness and flexural strength of Beautifil II were better than OliREVO composite.

Conclusion. Regarding the physical properties of composite resins, the microhardness and flexural strength may be compromised by bleaching treatments.

Keywords: Composite resins, Dental bleach, Microhardness, Flexural strength

Introduction

The pursuit of the ideal smile has significantly advanced cosmetic dentistry. Dental bleaching is one of a popular option for patients looking to improve the appearance of their smile, which can significantly improve aesthetics comparatively quickly [1]. Additionally, a survey done by Clinical Research Associates revealed that ninety one percent of dentists in their dental offices offered the dental bleaching treatment and seventy nine percent of such treatments were successful [2].

16 There are three main types of tooth bleaching products: at-home bleaching, in-office bleaching, and over-the-counter dental whitening products. Each type has its own benefits and drawbacks [3]. Peroxides, specifically "hydrogen peroxide (HP) and carbamide peroxide (CP)", which are either externally or internally applied to the tooth, are the basis of bleaching systems. However, pregnant or nursing women, as well as children under the age of 14, are not advised to undergo the bleaching treatment [4]. Factors influencing the efficacy of tooth bleaching include tooth stain type, bleaching agent concentration, type of bleaching system, and duration of application, as well as heat and light source [5,6].

Teeth discoloration 42 can be managed by a number of methods, including crowns, veneers, lumineers, and bleaching. The crown and veneers require removal of tooth structure, while vital tooth bleaching, in addition to being a less expensive alternative than bonded restoration, is also a conservative type of treatment [7,8].

44 In-office dental bleaching systems utilize a high concentration of bleaching agents, and this procedure is completely under the dentist's control. Whereas, at-home dental bleaching utilizes a low concentration of bleaching agent, and the patients undergo this treatment on their own under dentists' supervision during follow-up appointments [9].

In order to achieve tooth bleaching, the hydrogen peroxide (H_2O_2) is broken down, releasing free radicals, which go through oxidation/reduction processes. The double bond of pigmented molecules is split by these free radicals, resulting in smaller molecules, making the teeth look whiter by diffusing out of them or by absorbing less light [10].

Because the bleaching gels are in contact with the teeth and possibly any related restorations, there is a greater chance that it will result in unwanted changes, including softening and degradation of both dental hard tissue and restorative materials. Because of this, apprehensions about how bleaching may affect restorative dental materials have been expressed [11,12].

There are many types of direct restorative dental materials; one of these materials that is widely used today due to its esthetic properties is a composite resin [13]. Its organic matrix is more impacted by the chemical reactions than other aesthetic restorations including ceramic [14]. The surface of existing composite restorations may inadvertently come into contact with tooth-bleaching materials, altering and compromising their mechanical/physical properties [15]. As such, the dental clinician should be aware of any possible changes that applying the bleaching gels to composites may cause.

Quality and durability as well as the longevity of restorations are influenced by the physical characteristics of restorative dental materials, like that the micro-hardness, flexural strength, and fracture toughness [16]. In general, hardness is the ability to resist the permanent surface indentation or penetration [17]. In a sence, the flexural strength is a measure of tensile, compressive and shear stresses simultaneously. Rectangular bar specimens are used in the flexural strength test, and they are submitted to three or four point bending, this results in compressive stresses on the specimen's upper surfaces (the surface of the applied load is), and tensile stresses on their lower surfaces[18].

Although there is no doubt regarding the efficiency of dental bleaching in tooth color enhancement, the experimental data are rather controversial with no general agreement about the safety of this procedure on the restorative materials. Some authors reported that dental bleaching did not affect the composite resin [19,20] while others reported that some properties was changed after dental bleaching [21,22].

The study was undertaken to test the influence of three dental bleaching systems of various concentrations (home bleaching system and two in-office bleaching systems) on surface microhardness and flexural strength of the two resin composite restorative materials.

Materials and Methods

Two different brand nanohybrid resin composites of A2 shade and three bleaching regimens were used in this study. The composite resin materials were (Beautifil II, Shofu, Kyoto, Japan) and (OliREVO, Olident, Europe). The bleaching systems used were: home bleaching (Opalescence Go, 15% hydrogen peroxide, Ultradent Products, South Jorden, USA); in- office bleaching systems (Whiteness HP AutoMixx, 35% hydrogen peroxide, FGM, Brazil; and Opalescence Boost, 40% hydrogen peroxide, Ultradent Products, South Jorden, USA).

Samples grouping: For each test, forty-eight specimens were made, representing two main groups based on the type of resin composite, as follows:

Group I: 24 samples were prepared from Beautifil II composite resin

Group II: 24 samples were prepared from OliREVO composite resin

Then each main group was further allocated randomly into four groups based on the bleaching systems used, as follows:

Group (G1): the samples were bleached using Opalescence Go (n=6).

Group (G2): the samples were bleached using Whiteness HP AutoMixx (n=6).

Group (G3): the samples were bleached using Opalescence Boost (n=6).

Group (C): (control group) the samples were not undergo bleaching (n=6).

So the total number of groups for each test was eight.

Samples Preparation: For microhardness, the samples were made in a cylindrical teflon mold that measured 2mm in height and 5 mm in diameter[23]. A clean glass slab was used to place the mold on it. The composite resins were inserted in one increment in the mold, then covered with a transparent polyester strip. To remove the excess composite from the mold, microscopic glass slide was placed over the strip and pressed gently. After removing the glass slides, the samples covered with a polyester strip were cured with the aid of a dental light curing unit for forty seconds. After the completion of the light curing, the samples were taken out of the mold and they were polished using polishing discs (ViaDisc, Turkey) on a low speed-hand piece in the following order: medium, fine, and superfine discs.

For flexural strength, the samples were prepared and tested in accordance with a three point bending method specified in ISO 4049[24]. A rectangular split metal mold measuring 25.0 mm × 2.0 mm × 2.0 mm in length, height, and width, respectively, was used to prepare the samples. The composite resins were inserted in one increment in the mold, covered with a transparent polyester strip, then with a microscopic glass slide, gently pressed to remove any surplus material. After removing the glass slides, the samples covered with a polyester strip were cured using a dental light curing unit. Each specimen was cured at four overlapping places of forty seconds each along the mold's length.

Each composite sample was polymerized from the top surface at the right angle using the LED light curing unit. The output irradiance of the curing light was 1100 mW/cm^2, which was checked periodically every five exposures with an LED light tester. All photopolymerizations were taken at a constant room temperature of 23 ±1°C. To ensure complete resin polymerization, all samples were kept in distilled water at 37°C in an incubator for 24 hours [25].

Bleaching Process: Samples prepared of each resin composite were allocated at random into four groups (n = 6) based on the bleaching systems, as follows:

Group (G1): the samples were treated with opalescence go (15% HP). The top surface of each sample was treated with the bleaching gel for 20 minutes per day for one week.

Group (G2): the samples were treated with Whiteness HP AutoMixx (35% HP). The top surface of each sample was treated with the bleaching gel for 50 minutes per week for three weeks.

Group (G3): the samples were treated with Opalescence Boost (40% HP). The top surface of each sample was treated with bleaching gel for 20 minutes, three times in one session.

Group (C): the samples were not bleached, and they were kept in an incubator at 37 °C with distilled water for three weeks, representing the control group.

All bleaching procedures were performed in accordance with the manufacturer's directions. For standardizing the storage period in distilled water among all the groups, specimens of groups 3 and 1 were treated with bleaching for the last day and last week, respectively, of the three weeks of storage.

After bleaching, and in order to eliminate the bleaching gel, each sample was rinsed individually with distilled water and soft toothbrush for one minute, blotted dry, and then stored in distilled water at 37 °C during the entire experimental period. Daily, the distilled water was refreshed for all groups/samples.

Surface Microhardness and Flexural Strength testing: The microhardness measurement was done using Vicker's microhardness tester (OTTO Wolpert, WERKE GMBH/Germany), the indenter applying a load of 500 gram [26] and a dwell duration of 15 seconds. The indenter was positioned on the top (bleached) surface of each sample, three indentations were made, and the average microhardness value was calculated. The vicker hardness (VH) is determined using the following formula and expressed in kg/mm^2. VH=1.854P/d2.The P represents the applied load in kilograms, whereas d represents the arithmetic mean in millimeters of the two diagonals.

Flexural strength (FS) measurement was done utilizing a universal testing machine (GESTER, China) with a crosshead speed of 1mm/min. A three point bending method was utilized for testing the FS. On the bleached surface, each sample at its center was loaded till fracture occurs. The following formula: FS=3FL/2BH2 was used to calculate flexural strength in MPa. F represent the "maximum load (in Newton)", L represent the "distance between the supports" (20mm), B represent the "specimen's width" (2mm), and H represent the "specimen's height" (2mm).

Statistical Analysis: Using the Shapiro-Wilk and Kolmogorov-Smirnov tests, the normality of the data distribution was verified. The collected data were analyzed statistically using ANOVA and Duncan tests, utilizing SPSS Version 16. At $p \leq 0.01$, all statistical analyses were considered significant.

Results

The collected data were first evaluated for normality (Table 1). The data were then evaluated with Duncan test (Table 2) and (Table 3) to analyze the influence of bleaching agents on the hardness and flexural strength, respectively, of the used composite resins, and showed that bleaching agents reduce the hardness and flexural strength of composite resins, with a significant difference in the groups that were treated with 35 and 40% in-office bleaching systems. One-way ANOVA test (Table 4) was used to compare differences in the micro-hardness and flexural strength data among the groups; it indicated that the differences were significant among the groups. A two-way ANOVA test was employed to determine the effect of composite type, bleaching systems, and their interactions on both microhardness and flexural strength, and it showed that Beautifil II composite was significantly better than OliREVO in terms of hardness and flexural strength in all groups, except for the flexural strength of groups (G3), where the difference was no significant.

Discussion

Nowadays, most dental patients for aesthetic purposes request "whiter teeth", and tooth bleaching can be regarded as one of the easiest, fastest, and least invasive treatments with favorable outcomes and a relatively lower cost than other aesthetic restorative options [9,27].

Surface microhardness of resin composites is considered as one of the most crucial properties for the favorable durability of composite restoration, as the resin restorative material with greater microhardness has greater surface resistance to wear [28]. Because the Vickers microhardness technique is accurate for the methodology utilized, it was widely used in several in vitro investigations concerning microhardness [29-31]. Regarding flexural strength, the three point bending method that was followed in the current research is the choice for evaluating the flexural strength of composite resin materials, which is widely employed in dental research and is based on the International Organization for Standardization (ISO) specification no. 4049/2009 [24].

Hydrogen peroxide (HP) of 10–40% or carbamide peroxide (CP) of 10–22% is the basis of dental bleaching products [32]. When the bleaching agents are applied on the teeth, it's possible that they'll also come into contact with any pre-existing restorations, which may cause an oxidation reaction on restorative material's surface [33]. Therefore, efforts have been performed to investigate how bleaching agents affect the physical characteristics of dental resin materials, for instance, microhardness and flexural strength.

For many years, a large controversy has existed about the influence of bleaching on the microhardness of composite resin materials. Some studies, shown no significant changes in hardness [34-39], or an increase in surface hardness [40,41] or a significant reduction in the hardness subsequent to bleaching [42-46].

The current investigation evaluated the influences of two bleaching techniques at varying concentrations (at-home bleaching: 15% HP and in-office bleaching: 35% and 40% HP) on the surface microhardness and flexural strength of two commercially available nanohybrid composites (Beautiful II and OliREVO). Based on the results (Table 2), generally, the microhardness value of the bleached groups was less than that of the control group. This reduction was significant in the in-office bleaching groups that were treated with 35% and 40% HP. This reduction can be explained by the chemical softening effect of dental bleaching agents on the resin matrix of both composite resins, which thus decreased its microhardness [33,47]. Hydrogen peroxide (H_2O_2) is a potent oxidizing agent, as it generates free radicals. It is possible that peroxide induces oxidative cleavage of polymer-chains of restorative materials, causing the polymer chains to separate and the double bonds to break of the composite resin structure by producing free radicals. This could result in a softening and reduction in composite material microhardness [48]. Furthermore, peroxide-induced free radicals may adversely impact the filler-resin bond, result in filler-matrix debonding, create microcracks, and reduce microhardness[49]. This result agrees with Chakraborty *et al*. 2023[50] who stated that the microhardness of nanofilled composite decreased significantly after in-office bleaching with 35% HP. Additionally, these findings are consistent with Aleem *et al*., 2017 [51], who showed that in-office bleaching contained 38% HP and home bleaching consisted of 36% CP, significantly reduced microhardness of hybrid and nano-filled composite resins. Moreover, highly concentrated bleaching gels could be considered the strongest factor that might affect the composite resin's hardness. Hannig *et al*., 2007[48], reported that bleaching significantly lowered the microhardness of the adhesive filling materials and not only softens the surface of the adhesive restorative materials but also softens subsurface layers.

However, the reduction in microhardness was not significant (p>0.01) for the group that was treated with 15% HP home bleaching (table 2). This may be due to the lower concentration of the bleaching agent in this bleaching system, the higher the concentration of the peroxide, resulting in an increase in the disintegration of resin and the greater the reduction of the material's microhardness [52]. The compromising effects of bleaching treatments on already existing restorative materials are directly associated with the concentration of the used bleaching agents in addition to the length of time they are in contact with restoration materials [53]. Additionally, Campos *et al*., 2003 [54] showed that home bleaching techniques had no impact on the microhardness of the restoration's surface. In this context, this finding aligns with the result of Ye *et al*., 2008 [55] who showed that 15% CP did not significantly change the microhardness of the resin composites.

The negative impacts of bleaching treatment on the microhardness were also observed in flexural strength (Table 3). The reduction in flexural strength of resin-based restorative materials subjected to the bleaching treatments owing to the impact of free radicals from the bleaching chemicals on the resinous matrix [56]. As mentioned previously, the bleaching agent may bring about polymer-chains to undergo oxidative cleavage and affect the resin-filler interface of composite dental materials [57]. Firoozmand *et al*. (2009)[58] stated that the values of flexural strength of all the dental resin materials under study were significantly reduced by a bleaching treatment with 35% HP, this finding was consistent with the result of the current investigation. Furthermore, Hatanaka *et al*., (2013) [59] investigation found that 16% CP home bleaching gel was not affecting the flexural strength of different resin composites including (hybrid, nanofill, and micro-hybrid). Muralidasan *et al*., 2020 [60], studied the consequence of 10% CP and 35% HP bleaching agents on the property of the nano-hybrid composite in terms of its flexural strength, the author's findings indicate that the bleached groups presented a slight reduction in their flexural strength in contrast to the control group. Nevertheless, according to the results of Kalaivani *et al*., 2023 [33] the home bleaching regimen (10% CP) lowered the microhardness of micro-hybrid and nano-hybrid composites, while the flexural strength values was not significantly decreased.

According to the results of this study (Figures 1 and 2), generally, the Beautiful II composite resins possess better microhardness and flexural strength values than OliREVO composite resin before and after bleaching. This result may be explained by differences in composition between these two composite resins. Beautifil II is a composite of the Giomer category having S-PRG (Surface Pre-reacted Glass Ionomer) fillers. Kumar *et al*., 2023 [61] revealed that the inclusion of S-PRG fillers in dental composites increased some of their mechanical properties, including micro-hardness and flexural strength. The filler content by weight of Beautiful II and OliREVO is 83% and 82%, respectively, according to manufacturer information. The hardness and flexural strength of dental resin-based composites increased with the amount of filler[62]. In the study by Colceriu Burtea in 2019 [63], Beautifil II (a commercial giomer material) showed the greatest flexural strength value in comparison to experimental giomers. This finding of the current research comes in accordance with Parasher *et al*., 2020 [31] study, which showed that the Beautifil Bulk restorative (bulk-fill giomer) presented greater Vickers microhardness than non giomer bulk-fill. In addition, in accordance with Lien and Vandewalle, 2010 [64], who observed that the giomer Beautifil II showed Knoop values greater than those attained for silorane, micro-hybrid composite, and compomer. Additionally, the Beautifil II giomer composite presented a flexural strength value superior in both dry and wet conditions to that of other dental materials including compomer and glass ionomer cement[65]. This improvement in some mechanical properties of the giomer restorative material such as beautiful II might be attributed to S-PRG fillers[66], and to some extent, to the addition of various fillers including large pre-polymerized fillers, as well as S-PRG particles, amounting in total to 83.3 wt% [65].

Conclusion

Regardless of their concentration, dental bleaching can negatively influence the physical performance of composite resins. In-office bleaching agents significantly decreased the composite resins' microhardness and flexural strength. Therefore, complete replacement of composite restorations after bleaching procedure may be necessary.

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Table 1. Normal distribution of experimental data

		Tests of Normality					
Test/composite materials	Groups	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hardness/Beautifil	C	0.196	6	0.2*	0.919	6	0.5
	G1	0.174	6	0.2*	0.949	6	0.73
	G2	0.210	6	0.2*	0.894	6	0.34
	G3	0.228	6	0.2*	0.894	6	0.34
Hardness/OliREVO	C	0.306	6	0.083	0.881	6	0.27
	G1	0.206	6	0.2*	0.894	6	0.34
	G2	0.292	6	0.119	0.904	6	0.4
	G3	0.226	6	0.2*	0.884	6	0.29
Flexural Strength/ Beautifil	C	0.273	6	0.185	0.886	6	0.3
	G1	0.170	6	0.2*	0.947	6	0.72
	G2	0.182	6	0.2*	0.961	6	0.83
	G3	0.235	6	0.2*	0.874	6	0.24
Flexural Strength/ OliREVO	C	0.172	6	0.2*	0.960	6	0.82
	G1	0.164	6	0.2*	0.918	6	0.5
	G2	0.193	6	0.2*	0.941	6	0.7
	G3	0.217	6	0.2*	0.912	6	0.5

a Lilliefors Significance Correction
*This is a lower bound of the true significance.

Table 2. Duncan's test result for microhardness. Means with different letters indicate a statistically significant difference.

Composite materials	Groups (bleaching treatments)	Mean	N	Std. Deviation
Beautifil II	C (Control)	82.8730 a	6	4.19
	G1(15% HP home bleaching)	78.1540 a	6	4.23
	G2 (35% HP in-office bleaching)	61.6725 b	6	2.99
	G3 (40% HP in-office bleaching)	62.2058 b	6	8.23
	Total	71.2263	24	10.83
OliREVO	C (Control)	69.0723 a	6	4.62
	G1(15% HP home bleaching)	64.8403 a	6	2.74
	G2 (35% HP in-office bleaching)	41.3423 c	6	4.91
	G3 (40% HP in-office bleaching)	46.8615 b	6	3.19
	Total	55.5291	24	12.5

Table 3. Duncan's test result for flexural strength. Means with different letters indicate a statistically significant difference.

Composite materials	Groups (bleaching treatments)	Mean	N	Std. Deviation
Beautifil II	C (Control)	122.6 a	6	8.04
	G1(15% HP home bleaching)	121.16 a	6	8.62
	G2 (35% HP in-office bleaching)	102.68 b	6	7.42
	G3 (40% HP in-office bleaching)	94.71 b	6	9.5
	Total	110.28	24	14.5
OliREVO	C (Control)	110.58 a	6	5.07
	G1(15% HP home bleaching)	107.52 ab	6	7.08
	G2 (35% HP in-office bleaching)	97.92 c	6	6.36
	G3 (40% HP in-office bleaching)	99.78 bc	6	7.65
	Total	103.95	24	8.18

Table 4. ANOVA results for microhardness and flexural strength measurements.

		Sum of Squares	df	Mean Square	F	Sig.
Hardness/ Beautifil II	Between Groups	2137.695	3	712.57	25.433	0.0001
	Within Groups	560.337	20	28.02		
	Total	2698.032	23			
Hardness/ OliREVO	Between Groups	3279.059	3	1093.02	69.281	0.0001
	Within Groups	315.534	20	15.78		
	Total	3594.593	23			
Flexural Strength/ Beautifil	Between Groups	3419.224	3	1139.74	16.049	0.0001
	Within Groups	1420.306	20	71.02		
	Total	4839.530	23			
Flexural Strength/ OliREVO	Between Groups	662.821	3	220.94	5.055	0.009
	Within Groups	874.147	20	43.71		
	Total	1536.968	23			

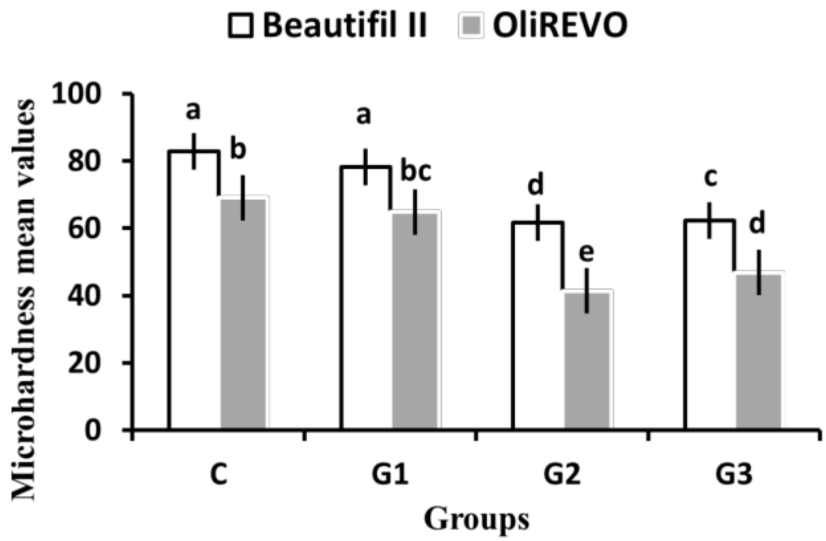

Figure 1. Histogram showing the influence of composite types, bleaching agents, and their interactions on the microhardness. Different letters indicate a significant difference.

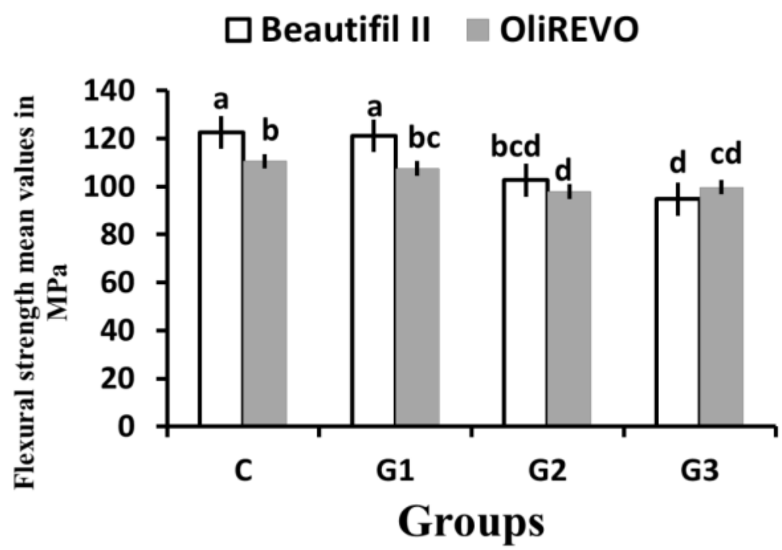

Figure 2. Histogram showing the influence of composite types, bleaching agents, and their interactions on the flexural strength. Different letters indicate a significant difference.