

Hydrogen peroxide bleaching: Effects on surface roughness, color and staining susceptibility of microhybrid and nanocomposite

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Abstract: Objectives. The current study aimed to investigate the effect of hydrogen peroxide bleaching on the surface roughness of microhybrid and nanocomposite and to compare the two materials regarding their staining susceptibility before bleaching, color response to bleaching and staining susceptibility after bleaching. **Materials and Methods.** Two dental composite materials, microhybrid (Filtek Z250) and nanocomposite (Filtek Z350), were bleached using two hydrogen peroxide bleaching agents: one home-bleach (DayWhite ACP) and one in-office (Opalescence Boost). Ten samples were tested for each composite-bleaching agent combination (n=10). An interface microscope was used to measure the arithmetical roughness (Ra) before and after bleaching. The color changes of the samples were measured four times using a spectrophotometer: a baseline measurement, a second time (after immersion in a coffee colorant), a third time (after bleaching) and finally the samples were immersed again in the colorant then a fourth measurement was made. Color differences between the different color measurements were calculated. **Results.** The roughness of the nanocomposite was more adversely affected by bleaching than the microhybrid with no significant difference between the two bleaching systems. The nanocomposite showed significantly more color change than the microhybrid when immersed in the colorant, both before and after bleaching. Bleaching did not affect the staining susceptibility of composite for all composite-bleaching agent combinations except for the microhybrid-home group where the staining susceptibility decreases after bleaching. **Conclusions.** The surface roughness of microhybrid composite is less adversely affected by bleaching than the nanocomposite. Nanocomposite is more prone to staining and more effectively bleached than microhybrid composite. Bleaching does not increase the staining susceptibility of nano or microhybrid composites.

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1. Introduction

Over the last few years, there has been a worldwide growing interest about beauty and aesthetics. This was reflected on the dental practice as a continuously increasing demand for tooth bleaching (El-Murr and St-Georges, 2011). Bleaching is a decolorization or whitening process based on treating teeth with some form of peroxide (hydrogen or carbamide peroxide) which produces free radicals. As the radicals diffuse into the tooth, they react with the organic colored materials called “chromophores” which are found within the tooth structure and are believed to be responsible for tooth staining. This reaction leads to the formation of less chromatic substances, thus, causes a reduction in tooth discoloration (Joiner, 2006). Tooth whitening can be achieved by either in-office or home bleaching regimens. In-office bleaching agents contain high concentrations (30-35%) of peroxides; thus, they should be applied by the dentist only for a relatively short time. On the contrary, home bleaching systems contain much lower concentrations (10-16%) of the

whitening agent; thus, they are safe enough to be self-applied by the patient for relatively longer durations (Attin *et al.*, 2004).

Patients seeking bleaching treatment may have some of their teeth restored with different kinds of aesthetic restorations, the most common among which are resin composites. The response of these existing restorations to bleaching affects the overall aesthetic result of the bleaching process. Also, any alterations in the surface topography or staining susceptibility of the resin composite due to bleaching may compromise the future aesthetic performance of the restoration (Costa *et al.*, 2009). A bleaching process that removes stains from composite but leaves it with a rougher staining-prone surface is definitely not considered a successful treatment.

Controversial results about the effects of bleaching on the surface roughness of different types of composite have been reported in literature. Rosentritt *et al.* (2005) and Hafez *et al.* (2010) reported that in-office bleaching adversely affected the surface roughness of microfilled and hybrid

composites. These findings were supported by Atali and Topbasi (2011) who found that the roughness of nanohybrid and nanofilled composites also increased significantly after office bleaching. Conversely, other studies reported that using in-office hydrogen or carbamide peroxide bleaching agents containing peroxide concentrations as high as 35% was not detrimental to the surface roughness of hybrid composites (Wattanapayungkul and Yap, 2003; Sharafeddin and Jamalipour, 2010). A controversy of results was also evident regarding the use of lower concentration home bleaching agents. Basting *et al.* (2005) found that using 10% carbamide peroxide increased the surface roughness of packable composite. On the other hand, Turker and Biskin (2003) reported that microfilled composites could be safely bleached with 10 or 16% carbamide peroxide without compromising their roughness. Wattanapayungkul *et al.* (2004) concluded that the effect of bleaching on the surface roughness of composite was material and time dependent.

Regarding the effect of bleaching on the color of composites, Villalta *et al.* (2006) reported that bleaching previously stained nano and microhybrid composites with office and home carbamide peroxide bleaching agents completely eliminated the discoloration and brought the samples' colors to the baseline values. Ayad (2009) and Pruthi *et al.* (2010) detected significant color changes of previously stained nanofilled and microhybrid composite samples after treatment with carbamide peroxide home bleaching systems. Other studies investigated the effect of bleaching on the color on composite samples that were not subjected to previous staining. Most of these studies reported that the color difference caused by bleaching was either insignificant (Costa *et al.*, 2009) or within the clinically acceptable range

($\Delta E < 3.3$) (Kim *et al.*, 2004; Hubbezoglu *et al.*, 2008; Li *et al.*, 2009; Anagnostou *et al.*, 2010) while only few investigations reported values higher than the acceptability limit (Ameri *et al.*, 2010). Canay and Cehreli (2003) reported that hydrogen peroxide bleaching caused more color changes in composites compared to carbamide peroxide agents of equal peroxide concentration. Although many studies investigated the effect of bleaching on the color changes of either stained or non-stained composites, only few studies tried to answer the question of whether bleaching makes dental composites more susceptible or more resistant to future staining. Celik *et al.* (2009) reported that bleaching of resin composites did not increase their susceptibility to extrinsic staining while Yu *et al.* (2003) found that bleached composites are more staining-prone than unbleached controls. The aim of the current study was to investigate the effect of hydrogen peroxide-based home and in-office bleaching agents on the surface roughness, color and staining susceptibility of both microhybrid and nanocomposites.

2. Materials and Methods:

2.1. Materials:

2.1.1. Resin composites:

Two resin composite materials were used in the present study, one microhybrid and one nanocomposite, both produced by the same manufacturer and based on the same type of organic matrix and inorganic fillers with almost the same fillers volume fraction.

2.1.2. Bleaching systems:

Two hydrogen peroxide-based bleaching systems, one in-office and one home-bleach, were used. Detailed information about the tested materials is shown in Table 1.

Table.1. Composite materials and bleaching agents used in the study.

Material	Product name and type	Composition (according to the manufacturers' data)		Manufacturer
Composite materials	Filtek Z250 (Microhybrid)	Resin matrix: BIS-GMA, BIS-EMA, UDMA with small amounts of TEGDMA*	Filler loading: 60 vol% silanized zirconia/silica particles (size range: 0.01 to 3.5 microns, average size: 0.6 micron)	3M ESPE Dental Products, St. Paul, MN, USA
	Filtek Z350 (Nanocomposite)		Filler loading: 59.5 vol% <ul style="list-style-type: none"> ▪ Non-agglomerated 20 nm nanosilica fillers ▪ Loosely bound agglomerated nanocluster formed of agglomerates of primary zirconia/silica particles with average size of 5-20 nm (cluster size: 0.6 to 1.4 microns) 	
Bleaching agents	Opalescence Boost (In-office)	38% hydrogen peroxide		Ultradent Products, USA
	Day White ACP (Home)	9.5% hydrogen peroxide		Discus Dental, USA

BIS-GMA: Bisphenol A diglycidyl ether dimethacrylate
TEGDMA: Triethylene glycol dimethacrylate

Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate
UDMA: Urethane dimethacrylate

2.2. Methods:

2.2.1. Sample preparation:

Twenty disc-shaped composite samples (20 mm diameter and 2 mm thickness) were prepared for each material using a custom-made Teflon mold. Each sample was built up as one increment. A glass slab was then placed on top of the mold to allow flushing the excess material and to obtain an upper smooth sample surface. The samples were then photopolymerized with a halogen light polymerizing unit (Nou Lite 10, Noutag, Switzerland) with light intensity of 650-800 mW/cm² using 40 seconds exposure for the samples' upper surfaces through the glass slab. The samples were then retrieved from the mold and their lower surfaces were also photopolymerized for 40 seconds. The cured samples were then stored in distilled water at 37°C for 24 hours, before any testing, to ensure complete polymerization.

2.2.2. Surface roughness analysis:

The initial (baseline) arithmetical surface roughness (Ra) was measured before subjecting the samples to any bleaching process. The measurements were carried out using an interference microscope (ZYGO; Maxim GP; ZYGP, USA) and the results were obtained by analyzing the measurement data using MetroPro software. For each sample, five roughness measurements at different regions on the sample surface were made and their average was taken as the final reading for that sample. The 20 samples of each material were divided into two groups, one group was subjected to a home bleaching regimen and the other was bleached with an in-office bleaching product. This gave rise to four groups representing different composite-bleaching system combinations: MH (microhybrid-home), MO (microhybrid-office), NH (nano-home) and NO (nano-office) (n=10). In the home bleaching process, the bleaching agent was applied to the samples 8 hours daily for 18 consecutive days. The bleaching agent was applied to the same sample surface every time, the surface that was allowed to set in contact with the glass slab, and the samples were then stored in a 37° C incubator during the bleaching period. After bleaching, the samples were thoroughly washed with water to remove the bleaching agent then stored in distilled water inside the incubator till the next day application. In the in-office bleaching, the samples were subjected to two bleaching sessions, each lasting for one hour as recommended by the manufacturer. A one-week time interval was allowed between the two sessions. To study the effect of bleaching on the surface roughness, the arithmetical roughness (Ra) was measured for a second time after

the bleaching process. For each group, the percentage change in roughness was calculated as follows:

$$\% \text{ change in Ra} = \frac{(\text{Ra}_{\text{after bleach}} - \text{Ra}_{\text{before bleach}})}{\text{Ra}_{\text{before bleach}}}$$

2.2.3. Color measurements:

The same four groups (MH, MO, NH and NO) were used to study the effect of bleaching on the color of resin composite and on its staining susceptibility. Each composite sample was subjected to four sequential color measurements as shown in Fig.1. Color measurements were made using a spectrophotometer (UV-3101PC Shimadzu Corporation, Tokyo, Japan) according to the CIE-L*a*b* color system. The CIE-L*a*b* system uses the three colorimetric coordinates L*, a* and b* where L* indicates the brightness of a color, a* describes the red-green content and b* describes the yellow-blue content.

An initial color measurement was made after sample preparation to determine the baseline color coordinates (L*₁, a*₁ and b*₁). The samples were then stained by immersion in a colorant (freshly prepared coffee) for three hours daily over a 50-days period. This gave rise to a total coffee immersion period of 150 hours. The same coffee powder/water ratio was used every day for preparing the colorant solution. After each daily immersion in coffee, the samples were removed from the colorant solution, thoroughly washed then stored in distilled water till the next day coffee immersion. At the end of the whole staining process, a second color measurement was made and the obtained CIE coordinates (L*₂, a*₂ and b*₂) together with those obtained from the first measurement were used to calculate ΔE*_{1,2} which represents the staining susceptibility before bleaching. Calculations were made using the following equation (Johnston,2009):

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The stained samples were then bleached with either the in-office or the home bleaching agent, using the previously explained protocols, then a third color measurement was carried out. The obtained coordinates (L*₃, a*₃ and b*₃) together with those obtained from the second measurement were used to calculate ΔE*_{2,3} which represents the color change caused by the bleaching process. To evaluate whether the color of the samples after the bleaching procedure returned to the baseline color, ΔE*_{1,3} was calculated using the coordinates of the first and third measurements.

The bleached samples were then stored in distilled water for two weeks to eliminate any

residual radicals that may have been left in the samples from the bleaching procedure. Finally, the samples were again subjected to a second staining process with exactly the same parameters as the staining process used earlier. After that, a fourth color measurement was carried out and the obtained coordinates (L^*_4 , a^*_4 and b^*_4) together with the third measurement coordinates were used to calculate ΔE^*_{3-4} which represents the staining susceptibility after bleaching.

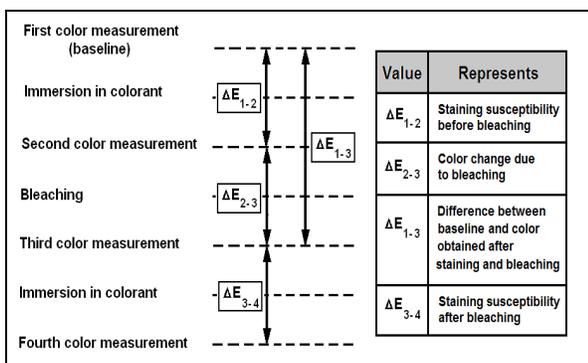


Fig.1. Sequence of treatments and color measurements (ΔE^*_{1-2} represents staining susceptibility before bleaching, ΔE^*_{2-3} is the color change due to bleaching, ΔE^*_{1-3} is the difference between baseline and color obtained after staining and bleaching, ΔE^*_{3-4} represents the staining susceptibility after bleaching).

2.2.4. Statistical analysis:

Data were presented as mean and standard deviation (SD) values. Wilcoxon signed-rank test was used to compare between (Ra) values before and after bleaching in each group. Mann-Whitney U test was used to compare between the two composite materials as well as to compare between the two types of bleaching agents. Kruskal-Wallis test was used to compare between the four groups. Mann-Whitney U test was used for pair-wise comparison between the groups when Kruskal-Wallis test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with PASW Statistics 18.0® (Predictive Analytics Software) for Windows.

®SPSS: An IBM Company, Chicago, IL, USA.

3. Results:

3.1. Results of the surface roughness:

Comparing the arithmetical roughness (Ra) of the two types of composites before bleaching revealed that the nanocomposite, surprisingly, showed significantly higher mean Ra value (0.013 ± 0.005) than the microhybrid type (0.007 ± 0.003). After bleaching, there was a statistically significant increase in Ra for most groups (MH, NH and NO) while the increase in Ra for the MO group was not statistically significant (Fig.2).

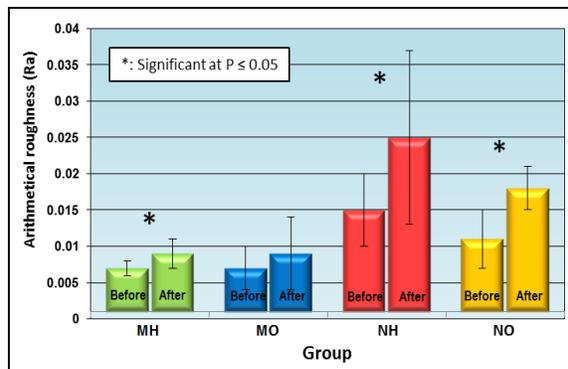


Fig. 2. Mean arithmetical roughness (Ra) of the four groups before and after bleaching

Comparing the % change in Ra for the four groups revealed that both NH and NO groups showed significantly higher % increase in Ra than the MH and MO groups. These results are shown in Table 2 while representative topographical microscopic images for the four groups, before and after bleaching, are shown in Fig.3. In addition, comparing the % increase in Ra caused by using either home and in-office systems revealed that there was no statistically significant difference between the effects of the two regimens on neither of the two materials (Table2).

Table 2. Comparison between the % increases in Ra after bleaching for the four groups

Microhybrid-Home (MH)		Microhybrid-Office (MO)		Nano-Home (NH)		Nano-Office (NO)		P-value
Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD	
28.6 ^b	13.3	24.3 ^b	13.8	72.6 ^a	36.2	74.4 ^a	37.3	0

*: Significant at $P \leq 0.05$. Means with different letters are statistically significantly different

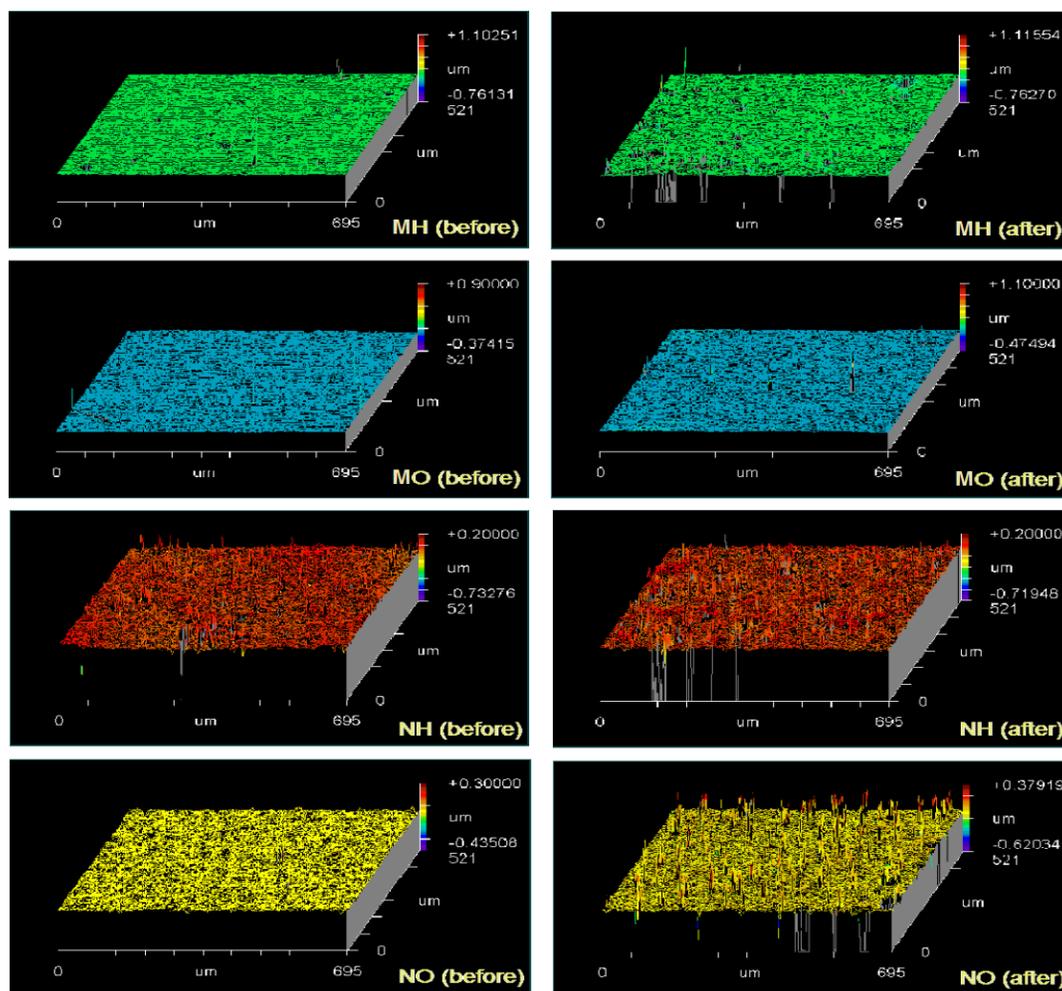


Fig. 3. Microscopic images showing the surface topography of representative samples for the four groups before (left) and after (right) bleaching.

3.2. Results of the color measurements:

The results of the color changes of the four groups are shown in Table 3. Regarding the ΔE_{1-2} , all nanocomposite samples and almost all microhybrid samples showed ΔE_{1-2} values that exceeded the “perceptibility limit”. The perceptibility limit represents the color difference that can be perceived or detected by 50% of the population and was found to be equal to $\Delta E=1$ (Johnston, 2009). The ΔE_{1-2} values of all microhybrid composite samples were less than the “acceptability limit” while 65% of the nano samples showed color difference values that exceeded this limit. The acceptability limit represents the color difference that is acceptable to 50% of the population and its value was determined as $\Delta E=3.3$ (Johnston, 2009). The nanocomposite groups (NH and NO) showed significantly higher mean ΔE_{1-2} than the microhybrid groups (MH and MO).

Concerning the ΔE_{2-3} , 70% of the MH samples and 40% of the MO samples showed values exceeding the perceptibility limit ($\Delta E=1$) while all nanocomposite samples (NH and NO groups) exceeded this value. Again, both nanocomposite groups (NH and NO) showed significantly higher mean ΔE_{2-3} than the microhybrid groups (MH and MO). There was no significant difference between the ΔE_{2-3} values of the two microhybrid groups (MH and MO). Also, no significant difference was found between the ΔE_{2-3} values of the two nano groups (NH and NO). This indicates that there is no significant difference between the two tested bleaching regimens, home or in-office, regarding their bleaching efficiency on either of the two tested materials.

As regards the ΔE_{1-3} , 50% of the MH, MO and NO samples showed values lower than the perceptibility limit while almost all NH samples showed ΔE_{1-3}

higher than this value. However, the ΔE_{1-3} values for all groups were lower than the acceptability limit ($\Delta E=3.3$). The NH group showed the statistically significantly highest mean ΔE_{1-3} while there was no significant difference between the other three groups that showed lower values. Regarding the ΔE_{3-4} , all

microhybrid samples showed values less than the acceptability limit ($\Delta E=3.3$) while 60% of both the NH and NO groups exceeded this limit. Both the nano groups (NH and NO) showed statistically significantly higher values than the microhybrid groups (MH and MO).

Table 3. The mean, standard deviation (SD) values and results of comparison between the ΔE s of the four groups

Color change	Microhybrid-Home (MH)		Microhybrid Office (MO)		Nano-Home (NH)		Nano-Office (NO)		P-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
E ₁₋₂	2.35 ^b	0.64	1.96 ^b	1.06	3.64 ^a	1.07	3.53 ^a	1.04	0.002*
E ₂₋₃	1.53 ^b	0.91	0.99 ^b	0.75	2.92 ^a	1.24	2.26 ^a	0.88	0.002*
E ₁₋₃	1.07 ^b	0.58	1.01 ^b	0.44	3.25 ^a	1.93	1.37 ^b	0.58	0.006*
E ₃₋₄	1.52 ^b	0.55	1.41 ^b	0.70	3.61 ^a	1.05	3.68 ^a	0.87	<0.001*

*: Significant at $P \leq 0.05$. Means with different letters (horizontally) are statistically significantly different

However, to answer the question of whether the bleaching process affects the staining susceptibility of composites or not, a comparison was made between the ΔE_{1-2} (staining before bleaching) and ΔE_{3-4} (staining after bleaching) within each group

(Table 4). The results revealed that for the MO, NH and NO groups, there was no statistically significant difference between ΔE_{1-2} and ΔE_{3-4} while for the MH group, the ΔE_{1-2} was significantly higher than the ΔE_{3-4} .

Table 4. The mean, standard deviation (SD) values and results of comparison between ΔE_{1-2} and ΔE_{3-4} within each group

Color change	ΔE_{1-2}		ΔE_{3-4}		P-value
	Mean	SD	Mean	SD	
Microhybrid-Home (MH)	2.35	0.64	1.52	0.55	0.007*
Microhybrid-Office (MO)	1.96	1.06	1.41	0.70	0.093
Nano Home (NH)	3.64	1.07	3.61	1.05	0.721
Nano Office (NO)	3.53	1.04	3.68	0.87	0.575

*: Significant at $P \leq 0.05$

4. Discussion:

Tooth bleaching is becoming one of the most popular cosmetic dental treatments. Since many patients demanding dental bleaching already have one or some of their teeth restored by resin composite, studying the effect of bleaching on the surface topography and color of resin composite became essential. Microhybrid and nanocomposites were selected in the current study since they are the most widely used resin composites in dental clinics nowadays.

Results of the current study showed that even before bleaching, the nanocomposite showed significantly higher baseline Ra than the microhybrid type. This may sound a little strange since most companies market their nanocomposites with the claim that they maintain smoother surfaces than the microhybrid types. This claim is actually true when the composites are subjected to mechanical friction.

In microhybrid composites, friction may cause dislodgement of the filler particles leaving depressions that roughen the surface. Friction with nanocomposites is believed to dislodge only the primary particles (nanomers) that constitute the clusters, not the clusters themselves, since the nanomers are loosely bound or agglomerated with each other. This would leave a grossly less rough surface (Mitra *et al.*, 2003; 3M, Filtek Z350 Universal Restorative technical profile, 2005). Since the samples in the current study were not subjected to frictional forces, this positive aspect of the nanocomposite was not evident. On the contrary, the presence of the nanoclusters near the surface and the possible dislodgement or shearing of large number of their loosely bound primary particles during sample preparation (i.e. separation from the glass slab) may have increased the initial roughness of the nanocomposite.

Three groups (MH, NH and NO) showed significant increase in roughness after bleaching. According to Durner *et al.* (2011), hydrogen peroxide may react with the C–C single or double bonds or the ester bonds that abundantly exist in most polymeric ingredients of dental composite. This may cause oxidative cleavage of the three dimensional polymer network which may result in topographic alteration of the composite. The silane coupling agent, that binds the fillers to the resin matrix, also contains these C-C bonds (Powers and Sakaguchi, 2006). If the bleaching peroxide degrades the coupling agent, the filler-matrix bond may get deteriorated to the extent that some fillers on the surface may get dislodged from the matrix leaving an even rougher surface (Kim *et al.*, 2004). This assumption is supported by the surface depressions that were commonly seen in the microscopic topographic images of many of the bleached samples (Fig.4). Such depressions may have been left behind after filler debonding.

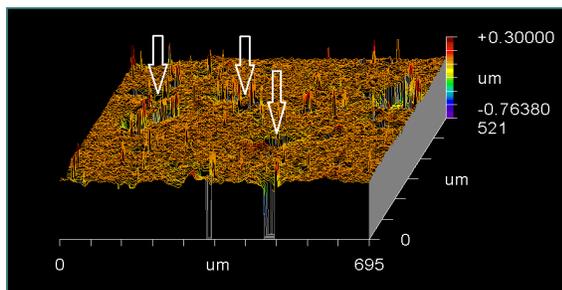


Fig.4. Microscopic image showing the surface topography of a bleached nanocomposite sample. The arrows show surface depressions that may have been left behind after fillers debonding

The results obtained in this study come in accordance with those reported by Rosentritt *et al.* (2005) and Hafez *et al.* (2010) who found that the roughness of microfilled and hybrid composites were adversely affected by in-office bleaching. Converse results were reported by Wattanapayungkul *et al.* (2003) who found that bleaching with 35% hydrogen peroxide was not detrimental to the surface finish of hybrid composites. This contradiction may be attributed to the difference between the two studies regarding the total time of bleaching agent application. In the current study, the bleaching agent was applied for a longer duration (two sessions, one hour each, as recommended by the manufacturer) while in the previously mentioned study, the agent was applied for a shorter total time (three sessions, 30 minutes each).

Also, Sharafeddin and Jamalipour (2010) found that in-office bleaching did not significantly affect

the surface roughness of microfilled and hybrid composites. However, the bleaching agent used in the latter study was based on 35% carbamide peroxide. Carbamide peroxide is an adduct of urea and hydrogen peroxide which upon contact with water breaks down to urea and hydrogen peroxide (Joiner, 2006). When a gel containing 35% (w/w) carbamide peroxide breaks down, it would actually yield a maximum of 11.55% (w/w) hydrogen peroxide which is far below the hydrogen peroxide concentration in the in-office agent used in the present study. It is noteworthy that the two last mentioned studies investigated the effect of bleaching on types of resin composites other than the nano type.

Both nano groups (NH and NO) showed significantly higher percentage increase in Ra compared to the microhybrid groups (MH and MO). Since both types of composite are based on the same type and almost the same volume fraction of resin matrix, this difference in roughness results may be explained by the difference in the pattern of filler loading. In microhybrid composites, the fillers are silanized before being added to the resin matrix. Thus, in case of a filler particle near the surface, the hydrogen peroxide can attack the coupling agent only on the surface around the circumference of the particle (Fig.5). The situation is different in case of nanocomposites. Nanocomposites possess a bimodal filler distribution consisting of non-agglomerated nanosilica particles as well as nanocluster formed of loosely bound agglomerates of primary zirconia/silica particles (3M, Filtek Z350 Universal Restorative technical profile, 2005). These agglomerated clusters are highly porous. During manufacturing, these nanoclusters are subjected to a “dual silanization” process before being added to the resin matrix. First, the clusters are infiltrated with a “dilute” silane coupling agent to help infiltration of the silane into the cluster interstices then, a second “undiluted” silane coupling agent is admixed with the ‘nanoclusters’ prior to incorporation into the resin matrix. However, it has been reported that even the infiltrated nanoclusters still possess some internal interstitial porosity (Curtis, 2008). This porosity may provide narrow pathways for the peroxide and for the produced radicals to diffuse through. Thus, the peroxide will not only attack the coupling agent at the surface, as in case of microhybrid composite, but it will be able to reach and degrade the coupling agent at even deeper levels leading to more filler debonding and subsequently more roughness. It also seems logic that the “dilute” coupling agent that infiltrates the clusters is more easily degraded chemically by the peroxide than the undiluted coupling agent that exist around the microparticles in the microhybrid composite. This may cause rapid deterioration of the

coupling agent inside the clusters leading to more dislodgement of the primary particles forming the clusters and consequently more roughness.

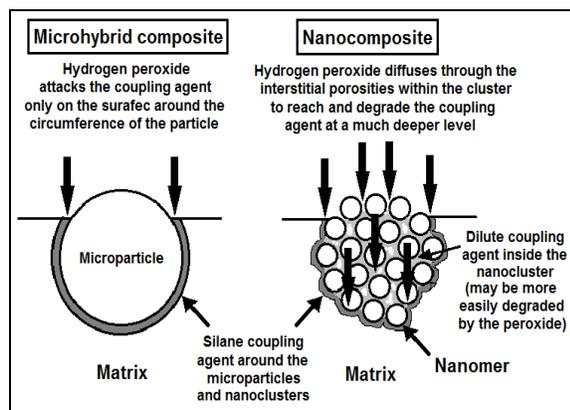


Fig. 5. The proposed effect of peroxide on the coupling agent of both microhybrid and nanocomposite.

Studying the effect of bleaching on the staining susceptibility of composite is also crucial. A bleaching process that effectively removes stains from a composite restoration but makes it more liable to future staining cannot be considered a successful treatment. The staining susceptibility of composite was evaluated before and after the bleaching process. The staining susceptibility was measured by measuring the color of the samples before and after immersion in a colorant solution. Coffee was chosen as a staining solution because of its proven strong staining effect on composites (Awliya *et al.*, 2011). The average time needed to consume a cup of coffee was estimated to be 15 minutes. Coffee drinkers ingest an average of 3.2 cups of coffee per day (Hafez *et al.*, 2010). Therefore, 150 hours of storage in a coffee solution, the duration used in the current study, simulated an average of six months coffee consumption. Discoloration of resin-based restorative materials by coffee is believed to be caused by both adsorption and absorption of the colorant on and into the material respectively (Um and Ruyter, 1991).

Color measurement results revealed that after initial staining, almost all samples showed perceptible ΔE_{1-2} with the ΔE_{1-2} values of many of the nanocomposite samples exceeding even the acceptability limit ($\Delta E=3.3$). The two nano groups showed significantly higher ΔE_{1-2} values than the microhybrid ones indicating that even before any bleaching process, the nanocomposite was more susceptible to staining than the microhybrid type. These results come in accordance with those previously reported by Vilata *et al.* (2006) and Awliya *et al.* (2011). Since both tested materials are

based on the same type and volume fraction of the resin matrix, the difference in staining susceptibility may be attributed to the difference in the nature of filler system. It's possible that the very narrow interstitial porosities that exist within the nanoclusters act as fine capillaries which exert a capillary action that draws or drains the staining solution into the clusters. The situation is different in case of the microhybrid composite where these porosities do not exist. This may make the microhybrid composite more resistant to the colorant solution penetration.

Comparing the ΔE_{2-3} values showed that both types of bleaching agents caused more pronounced color change in the nanocomposite than in the microhybrid type. Based on the same previously discussed concept, the interstitial porosities that allow the peroxide and the produced radicals to penetrate through and to interact with and oxidize more deeply situated stains. Comparing the efficiency of the two bleaching regimens surprisingly showed that the in-office product was not any superior than the home bleaching agent. This comes in agreement with Cunha *et al.* (2011) who reported that extending the duration of the home bleaching protocol to a minimum of 14 days would make the home bleach as efficient as the in-office treatment. It is possible that the washing out of the oxidized stains after each home bleaching session increases the ability of the bleaching agent to interact with more new stains during the next application. This mechanism may increase the efficiency of home bleaching so that it produces comparable results as the in-office products despite the much higher peroxide concentration in the latter.

The ΔE_{1-3} values (difference between the baseline color and the color obtained after staining followed by bleaching) for all groups were lower than the acceptability limit ($\Delta E=3.3$). This means that the bleaching process succeeded to reduce the color change caused by staining to an acceptable range for all composite-bleaching agent combinations. It is important to highlight that many of the previous studies that addressed the effect of bleaching on the color of composite measured the color difference before and after bleaching without subjecting the composite to previous staining process (Kim *et al.*, 2004; Yalcin and Gurgan, 2005; Hubbezoglu *et al.*, 2008; Li *et al.*, 2009; Anagnostou *et al.*, 2010; Ameri *et al.*, 2010). Thus, these studies only investigated the effect of bleaching agent on the chemistry of composite without studying whether the bleaching agent was capable of removing the stains from the composite material or not. This does not actually represent the real clinical situation because most of

the composite restorations subjected to bleaching are already stained and it is crucial to study how they would respond to the whitening process. The results of such studies cannot be compared with those of the present study which involved a staining stage before bleaching.

Regarding the $\Delta E_{3.4}$, both microhybrid groups showed clinically acceptable values while more than half of the nano samples exhibited clinically unacceptable color changes. Both the nano groups (NH and NO) showed statistically significantly higher values than the microhybrid groups (MH and MO). This indicates that also after bleaching, the nanocomposite remained more prone to staining than the microhybrid type.

Comparing the staining susceptibility before and after bleaching for each group showed that the staining susceptibility of the MO, NH and NO groups was not affected while the MH group became more stain-resistant after bleaching. This comes in agreement with the results reported by Celik *et al.* (2009) who found that bleaching did not increase the staining susceptibility of dental composites. Taking into consideration that the surface roughness of composite increased after bleaching, it was expected that this would lead to increased susceptibility to extrinsic staining but this was not actually the case. It is possible that the interaction of the peroxide with the polymer network results in alteration of the polymer surface energy or chemistry in such a way that decreases its tendency to absorb or adsorb the colorant solution.

Conclusion:

Hydrogen peroxide bleaching may adversely affect the surface roughness of microhybrid and nanocomposite with the latter being more affected. Nanocomposite is more prone to staining than the microhybrid type and it is also more effectively bleached. Bleaching does not increase the staining susceptibility of either of the two types of composites.

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