Color Change of Two Different Nano-Hybrid Resin Composite Materials after Staining and Bleaching. (An *in vitro* Study)

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Abstract

Purpose: To investigate the effects of staining and bleaching on color change of two different Nano-Hybrid resin composite materials.

Materials and Method: In total, 48 samples were fabricated (24 samples from each Nanotype). Samples of each composite group were sub-divided into three sub-groups (n=8). Samples of *Stain sub-groups* immersed in coffee solution for 48 hours at 37°C; in *Stain Bleach sub-groups*, samples were stored in coffee solution for 48 hours at 37°C then bleached with 30%H_2O_2; in *Bleach sub-groups*, samples were bleached with 30% H_2O_2. After that, color measurements were recorded again for each sub-group.

Results: After staining and bleaching, all sub-groups of both tested materials demonstrated clinically acceptable color change ($\Delta E<3.3$) with significant differences ($P<0.05$).

Conclusion: Color change of the two tested materials do not affected by staining and bleaching.

Keywords: *Composite resin, color change, staining, bleaching, hydrogen peroxide.*

Introduction

The esthetic success of resin composite restorationdepends greatly on its optical appearance and color match with the surrounding natural dentition; to render a restoration imperceptible, restoration materials should reproduce color of natural teeth and maintain long-term colorstability and resistance todiscoloration(1). Many parameters affect the colorstability of resinous materials liketype and volumeof resin material, size and typeof filler particles, and the coloring agents. Extrinsic discoloration can be caused by dietary and smoking habits, and adsorption or absorption of water-soluble stains within the composite organic matrix (2). Stains can be removed partially or totally by brushing with toothpastes, polishing and bleaching.; tooth bleaching is considered a conservative, easy and efficient methodforteeth whitening, and nowadays, tooth bleaching has become a routine treatment in common dental practice. Bleaching treatments can improve the color of discolored teeth and,at the same time, may yield color alterations of the existed composite restorations on teeth; also, composite restorations might undergo changes due to softening effectsof bleaching which ultimately affect their clinical durability (3).With the application of Nanotechnology to dental composites, Nano Hybrid composites have been used as restorative materials for their favorable mechanical properties. However, there is a controversy regarding their color stability after staining and bleaching. Therefore, this study investigated the color change of two Nanohybrid composite materials after staining by coffee and bleaching with 30% hydrogenperoxide. The null hypothesis suggested that staining and bleaching have no influence on color of both tested materials.

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Materials and Method

Samples Fabrication: Twoesthetic Nano Hybridcomposite materials (Joyfil Nano hybrid composite, and Omnichroma resin based composite) were tested in this study (Table 1). In total, 48 disc samples (24 samples from each Nanotype), 5 mm in diameter and 2 mm in thickness, were fabricated using Polyurethane mold. The mold was placedon a transparentcelluloid matrixover a glass slab and filled with the tested material, then the surface of the mold was covered with anothermatrix and a glass slab.A 500g load was placedfor 30 seconds on the topof eachsampleto allow the excess material to leak out[4]. Load was then discontinued and thesamplewas light cured for 40 seconds using (LED light curing unit,Blue phase,Woodpecker, China) with 1000mW\cm^2 light intensity. Specimens were stored in artificial saliva at 37°C for 24 h[5]. Specimensof each composite material were divided intotwo majorgroups:

Gp1: Joyfil composite. (24 samples),

Gp2: Omnichroma composite. (24 samples).

Each composite group was further randomly subdivided into three sub-groups, each of which contained 16 samples (8 samples of each composite type) as follow:

- **Stainsub-groups:** Specimens were stained by incubating the samples in coffee solution at 37°C for 48 hours, then color change measurements were recorded.
- **Stain Bleach sub-groups:** Firstly, specimens stained in coffee solution for 48 hours then chemically bleached by 30% H_2O_2 gel; after that, color change measurements were recorded.
- **Bleach sub-groups:** Specimens were chemically bleached with 30% H_2O_2gel then color change measurements were recorded.

Table (1): Materials used in the study

Material name	Type	Composition	Manufacture
Joyfil	Nano Hybrid universal composite (Shade:A_2)	**Matrix:** BIS-GMA **Filler:** Non- agglomerated 7 nm nano-silica filler in size and aggregated schott glass/silicanano-cluster filler. Range is 0.7µm (74%w, 58.89%v)	3D Dental, USA
Omnichroma	Nano Hybrid composite (Universal shade)	**Matrix:** 1,6(methacryl ethyloxycarbonylamino), UDMA,TEGDMA. **Filler:** Spherical silica-zirconia filler. Ranging from 0.2-0.6micron (Mean particle size is 0.3µm (79%w, 68%v).	Tokuyama Dental,Japan
Dash Chairside whitening system	In-office chemical bleaching	30%Hydrogen peroxide	Philips,USA

Staining Method: Samples of Stain and Stain Bleach sub-groups of both composite materials were stained by coffee solution which was prepared by mixing (1.5g) of coffee powder (Nescafe Classic,Nestle,Indonesia) in 120 ml of boiling water according to manufacturer's instructions. Samples of both sub-groups were incubated in coffee solution for 48 hours at 37°C[1]. After staining, samples of Stain sub-groups were washed with distilled water and air-dried to be ready for recording color measurements, while samples of Stain Bleach sub-groups were rinsed with distilled water and incubated again in artificial saliva at 37°C until performing bleaching procedure.

Bleaching Procedure: Samples of Stain Bleach and Bleach sub-groups were chemically bleached with 30% H_2O_2 (Dash Chairside whitening system, Philips,USA). Bleaching gel was applied in an equal amount on the specimen for 45 minutes in three cycles, each cycle lasted 15 minutes according to manufacturer's instructions. After bleaching, samples were washed under running water for 1 minute to eliminate bleaching material remnants and then air-dried before color measurements were recorded.

Color measurement procedure: Color measurements were taken first for all sub-groups using VITA Easyshade®V Spectrophotometer and considered as initial data. After staining and bleaching procedures, color measurements were taken again for all samples

of both materials. VITA Easy shade is a simple click digital spectrophotometer that provides an instant shade read out. The measurements depend on the CIE L*a*b* (Commission International del'Eclairage) colorsystem toper form color change test [6]. Coloris measured in three coordinate dimensions: L* refersto lightness and its value range from (0) for perfect black to (100) for perfect white; the a*value is a measure of red-green axis, ($^{+}$a*=red,−a*=green); the b*value is a measure of yellow–blue axis, ($^{+}$b*=yellow,−b*=blue)[5]. Measurements were repeated for 3 times for each specimen and color change (ΔE) values were recorded according to the formula

$$\Delta E^* = \sqrt{(\Delta L^*) + (\Delta a^*) + (\Delta b^*)}$$

Statistical analysis: Normality test was used to check the normal distribution of the data and non-parametric tests were chosen since the data follow abnormal distribution. Friedman's test of related samples was used to test the significance of staining and bleaching at P<0.05 among and between the three sub-groups of both tested materials. Mann-Whitney U Test for independent samples was used to compare (ΔE) mean values between every two similar sub-groups of the two materials.

Results

The ΔE* values of all sub-groups were recorded and analyzed. According to many studies there are three different intervals for(ΔE): ΔE<1, imperceptible by human eye, 1<ΔE<3, recognizedonly by skilled persons; and ΔE ≥3.3, easily observed by human eye (clinically unacceptable) [1]. Mean and standard deviationof (ΔE) values are displayed in Table(2). All sub-groups of the twomaterials showed clinically acceptablecolorchange (ΔE<3.3). Friedman's test demonstrated significant differences (P<0.05) in colorchange among all sub-groups forboth tested materials as demonstrated in Table(3). As the sub-groups ofboth materials were significantly different, Friedman's test was used again tocompare each twopairsof sub-groups in both materials to indicate the difference between which sub-groups. In Joyfil composite sub-groups, there were significant differences (P<0.05) between Stain sub-group with both Stain Bleach and Bleach sub-groups. However, no significant difference (P>0.05) was seen between Stain Bleach and Bleach Joyfil sub-groups. For Omnichroma sub-groups, the results showed significant difference (P<0.05) between Stain Bleach and Bleachsub-groups. In contrast, there was no significant difference (P>0.05) between the other pairs of sub-groups as seen in Table(4). Mann-Whitney U Test used to compare the (ΔE) mean values of each two similar sub-groups of both composite materials, the results revealed significant differences (P<0.05) between Stain sub-groups and also between Bleach sub-groups. However, no significant difference (P>0.05) was seen between Stain Bleach sub-groups of both materials as seen in Table(5) and Figure(1).

Table (2): Mean and standard deviation of Color Change (ΔE) for all sub-groups of both tested materials

	Joyfil (ΔE)		Omnichroma (ΔE)	
Sub-groups	Mean	Std. Deviation	Mean	Std. Deviation
Stain	3.2	0.382324	2.03375	0.587001
Stain Bleach	1.64	0.822540	1.68750	0.339695
Bleach	2.04875	0.252102	2.47125	0.414882

Table (3): Comparison of (ΔE) values among all sub-groups of both tested material

Test	Joyfil		Omnichroma	
	Test statistic	Sig	Test statistic	Sig
Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	13	0.002	10.750	0.005

Table (4): Comparison the (ΔE) values for each two pairs of sub-groups for both tested materials.

Joyfil	Test Statistic	Sig	Omnichroma	Test Statistic	Sig
Pair 1 SB sub-g – B sub-g	-0.500	0.952	Pair 1 SB sub-gp – S sub-gp	0.625	0.634
Pair 2 SB sub-g– S sub-g	1.750	0.001	Pair 2 SB sub-gp – B sub-gp	-1.625	0.003
Pair 3 B sub-g – S sub-g	1.250	0.037	Pair 3 S sub-gp – B sub-gp	-1.000	0.137

(S sub-gp: Stain sub-gp, SB sub-gp:Stain Bleach sub-gp, B sub-gp:Bleach sub-gp).

Table (5): Comparison between the (ΔE) mean values for all sub-groups of both tested materials.

(ΔE) of sub-groups of Joyfil and Omnichroma composites	Test statistic	Sig
(ΔE) S sub-gp (Joyfil) and (ΔE) S sub-gp (Omni)	3.000	0.001
(ΔE) SB sub-gp (Joyfil) and (ΔE) SB sub-gp (Omni)	41.000	0.382
(ΔE) B sub-gp (Joyfil) and (ΔE) B sub-gp (Omni)	52.0000	0.038

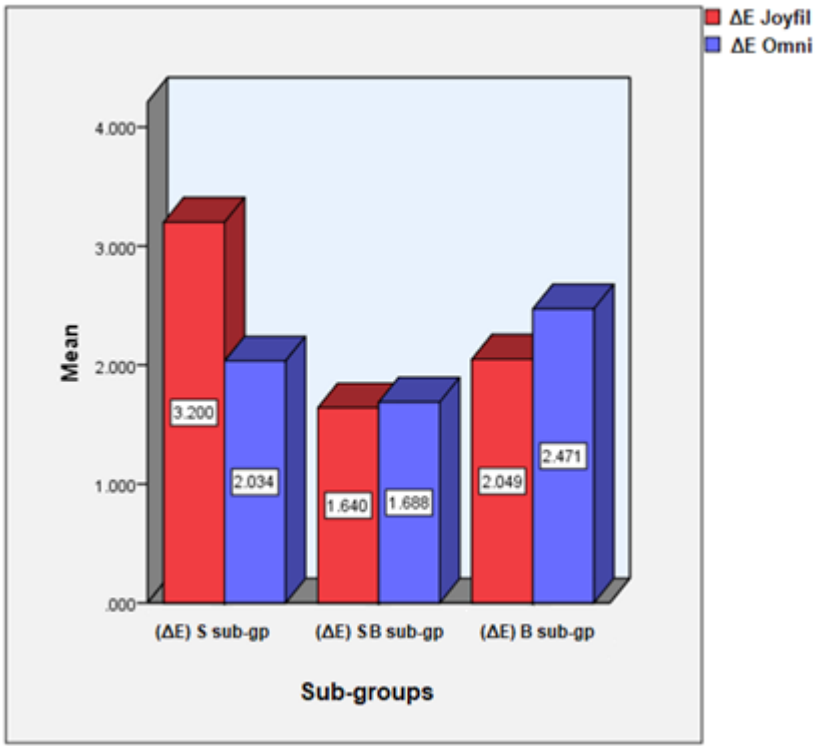

Figure (1): Comparison between the mean of (ΔE) values for each two similar sub-groups of both tested materials.

Discussion

Resin composites are frequently used esthetic restorations in dentistry for their excellent aesthetic properties and adequate strength; composite restorative materials should mimic the appearance of natural teeth and one of main causes for replacement of restorations is when they reflect unacceptable color match with the surrounding dentitions[7]. For achieving desirable esthetics in dentistry, composite restorations should be able to maintain intrinsic color stability and resistance to surface staining. However, over time, composite restorations in the oral environment acquire external stains and develope internal discoloration which may be explained by the biphasic nature of the material (composed of matrix and fillers) that facilitates inclusion of external stains in its structure[8]. Coffee was selected in this study because it is frequently consumed beverages and it has a strong potential to stain teeth and restorative materials. Many studies have used coffee as a staining solution[1,3,7,9,10] and according to coffee manufacturers,

it requires an average of 15 minutes to drink a cup of coffee; coffee drinkers consume an average of 3.2 cups of coffee per day; therefore, specimens storage in coffee solution for 48 h equals an average of two months of coffee intake [9]. The findings of the present study showed that coffee induced clinically acceptablecolorchange (ΔE<3.3) in specimensof stain sub-groups for both tested materials with significant differences (P<0.05) between the two sub-groups. Discoloration by coffee attributed tobothabsorption and adsorptionofpolarcolorantsonto the surface of materials [7]. Another reason can be related to fluid uptake by resin composites as when composite can absorb water, so it can absorb othercoloredsolutions; the increase in fluid uptake was relatedtoincorporationof hydrophilic monomers in composite resin matrix. Bis-GMA and TEGDMA are hydrophilic monomers, but fluid uptake in Bis-GMA increased from 3 to 6%, while in TEGDMA it increased from 0 to 1%[2]. AlthoughpresenceofBis-GMA and TEGDMA in the twotested materials, their colorchange after staining was clinically acceptable. However, Omnichroma Stain sub-group was significantly less than Joyfil Stain-sub-group which can be attributed to the presenceof UDMA in its resin matrix which is more stain resistant than Bis-GMA with low water sorption and solubility. The acceptablecolorchange and low staining susceptibility after staining forboth tested materials can be explained by low resin content in the twomaterials (26% for Joyfil and 21% for Omnichroma). The findings of this study came in agreement with the results ofsome studies whoobtainedacceptablecolorchange (ΔE<3.3) of resin composites after staining with coffee [1,11]. In contrast, other studies found that coffee had induced severe clinically unacceptable staining (ΔE>3.3) of resin composite samples[3,7,9,10]. This discrepancy in results were probably related to differences in staining methodologies like the typeof immersionsolution and immersion time; also, the differences in chemical compositionof resin composite used may affect the results.

The interaction between bleaching agents and composite materials is of clinical significance and should be focused on; the bleaching system used in the current study was chemically activated with 30%H_2O_2. Hydrogen peroxide is a strong oxidizing agent that generates free radicals which have an extensive ability for diffusion and penetration the surface of composite materials then producing degradation of polymer network; thus, a resin composite with higher resin content is expected to be more pronounced to degradation and subsequently may undergo more colorchange [12].

Ideally, bleaching after staining would be considered good if (ΔE) values decreased and perfect if (ΔE) values are equal tozero because this means that the restorative materials have returned to their baseline colorbefore staining [1]. The findings ofthis study showed that bleaching after staining for both Joyfil and Omnichroma Stain Bleach sub-groups also gave acceptable color change (ΔE<3.3) with no significant differences (P>0.05) which refers to that bleaching following staining was effective in reducing the discoloration for both tested materials as the (ΔE) values after bleaching were decreased from the (ΔE)obtained after staining. These results came in accordance tosome studies that found bleaching treatments have decreased (ΔE) values of composite tested materials to a clinically acceptable level even after severe colorchange due to staining; they attributed this to superficial cleansing of the specimens by bleaching agents not due to internal bleaching[8,13]. In contrast with these results, others stated that bleaching after staining with a high concentration of H_2O_2 gave high and unacceptable color alteration (ΔE>3.3) for the tested materials and explained their results that high concentrations of H_2O_2 may cause chemical softening of restorative materials leading to more colorchange [1,14].

After bleaching, (ΔE) values ofboth tested materials for bleach sub-groups were also within the acceptable range (ΔE<3.3). However, the (ΔE) values of Omnichroma study samples was significantly higher (P<0.05) than that of Joyfil study samples. Omnichroma composite has average filler particles size of 0.3μm and lower amount of resin matrix (21%) by weight with different percentages of UDMA and TEGDMA, so it is expected to show low color change, but the results demonstrated the opposite. In contrast, Joyfil is Bis-GMA based resin material with average filler particles size of 0.7μm and resin matrix of (26%) by weight, but it showed less colorchange compared to Omnichroma resin composite. This finding may be explained by the differences of bond interfaces between resin matrix and fillers or the type of prepolymerized filler particles incorporated in these two materials that mayinfluence the effect of bleaching agent on them.

With respect to comparison of (ΔE) values among the three sub-groups in each tested material, the results showed significant difference among all sub-groups of the two tested material which may refer to that staining

and bleaching can change the color of tested samples but with acceptable levels.

Some limitations in this study can be pointed out like immersion of study samples in a single type of staining beverage; which can't reflect the actual staining potential of human dietary behavior. Also, this is an *in vitro* study, so it is impossible to directly mimicoral conditions because food and beverages ingestion is a dynamic process that doesn't allow sustained static retention of stain in the oral cavity.

Conclusion

1. The two Nano-Hybrid composite tested materials reacted similarly to staining and bleaching.
2. Staining by coffee and bleaching by 30%H_2O_2 didn't influence the color of both tested materials as ΔE values were within acceptable range ($\Delta E<3.3$).

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both MOH and MOHSER in Iraq

Conflict of Interest: None

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