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Color Stability and Microhardness of Nanocomposite Resins Exposed to Different Staining Solutions: *In Vitro* Study

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Received: December 04, 2019; **Published:** December 30, 2019

Abstract

Background: Nanotechnology revolutionized the dental field through the development of resin materials with more suitable mechanical properties. However, the main disadvantage of composite restoration is discoloration to upon prolonged exposure to oral environments. The color stability and microhardness values of three nanocomposite resins immersed in different staining solutions were investigated.

Materials and Methods: A total of 45 disc-shaped specimens (12.0 mm × 2.0 mm) were prepared from three nanocomposites (Filtek Z350, Filtek Bulk Fill, and Grandio; fifteen specimens per material). Each group was then randomly subdivided into three groups according to staining solutions; immersed in artificial saliva (control group), Arabic coffee, and Coca Cola (n = 5). The microhardness and colors measurement of the composite specimens were measured at baseline and after 7, 14, 21 and 28 days of immersion in staining solutions. The data analyzed using analysis of variance and Tukey's multiple comparison tests at significance level $p < 0.05$.

Results and Conclusion: Significant differences were found in the color measurement values (ΔEab) of the three brands of composite after 28 days of staining procedure. Filtek Z350 (1.38 ± 0.09) significantly differed from Filtek Bulk Fill (0.95 ± 0.01) and Grandio (1.09 ± 0.06). The specimens immersed in cola exhibited the most significant color changes compared to saliva and coffee.

Similar significant differences were observed in the hardness of the three types of specimens. The highest hardness value was observed for Grandio (96.60 ± 1.51), followed by Filtek Z350 (72.13 ± 2.10) and Filtek Bulk Fill (53.19 ± 1.83) ($P < 0.05$) at the baseline. The specimens immersed in saliva (control) exhibited increased hardness after 28 days of immersion, whereas the specimens stored in coffee and cola exhibited decreased hardnesses.

The nanocomposites investigated in the present study exhibited significant color changes upon immersion in Coca Cola solution for 28 days. Similarly, the micro-hardness values of Filtek Z350 and Filtek Bulk fill decreased after immersion in the tested staining solutions.

Keywords: *CIELAB; Color Stability; Composite Resins; Microhardness; Nanocomposite*

Introduction

The introduction of nanotechnology enabled the production of functional materials and structures in the size range of 0.1 - 100 nm using various chemical and physical processes. Nanotechnology revolutionized the dental field through the development of resin materials with more encouraging mechanical properties [1,2]. Based on the concept of nanotechnology, a class of composites referred to as nanocomposites were recently developed and marketed [3]. Nanocomposites combine the good mechanical strength of hybrids and the excellent polish ability of microfills [2]. In addition, nanocomposites demonstrate high wear resistances, improved optical characteristics, and reduced polymerization shrinkage [2,3].

However, the main disadvantage of composite restoration is the discoloration when exposed to oral environments for long time-periods [4]. In previous studies, it was demonstrated that commonly consumed beverages and food ingredients may have a significant influence on the color of composite resin restorations [5,6].

The clinical longevity of a restoration is determined by the physical characteristics of the restorative materials [6,7]. One such characteristic is the hardness of the composite resin. Hardness can be defined as the resistance of a material to indentation or penetration and abrasion [7,8]. This hardness of the material related to the compressive strength, wear resistance, and degree of conversion (DC%) [9,10]. Moreover, microhardness measurements are also influenced by the type and volume percentage of the filler, the storage conditions, and the presence/absence of an oxygen-inhibited layer [11]. Vickers hardness tests are commonly used to measure the microhardness of the restorative materials [12,13].

In previous studies, the excellent color stability and high surface luster of the nano-filled and nanohybrid composites were mainly reported [1,14,15]. However, reports on the color stability and microhardness of the recently marketed nanocomposite materials (Filtek Bulk Fill, Filtek Z350 universal and Grandio) are limited.

Aim of the Study

The aim of this *in-vitro* study was to investigate the color stability and microhardness of three nanocomposite resins exposed to staining solutions (artificial saliva, Arabic coffee, and cola) for 28 days.

Materials and Methods

Composites used in the study

In this study, the color stability and microhardness of three nanocomposites were evaluated. The composites used in the study are listed in table 1.

Composite	Shade	Composition		Manufacturer
		Resin matrix*	Inorganic filler (wt. %)	
Filtek Z350	A2	Bis-GMA, UDMA, TEGDMA, Bis-EMA	Silica Zirconia (72.5 wt. %)	3M ESPE, St. Paul, MN, USA
Filtek Bulk Fill	A2	Bis-GMA, Bis-EMA, UDMA	Zirconia (64 wt. %)	3M ESPE, St. Paul, MN, USA
Grandio	A2	Bis-GMA, TEGDMA	Barium-boron-alumino-silicate glass (87 wt. %)	Voco, Cuxhaven, Germany

Table 1: *The Nano-Composite resins used in the present study.*

**Bis-EMA: Ethoxylated Bisphenol A Dimethacrylate; UDMA: Urethane Dimethacrylate; EBADMA: Ethoxylated Bisphenol A Dimethacrylate; Bis-GMA: Bisphenylglycidyl Dimethacrylate; TEGDMA: Triethylene Glycol Dimethacrylate.*

Preparation of composite specimens

Fifteen disc-shaped specimens with diameters of 12.0 mm and thicknesses of 2.0 mm per composite resin material (A2 shade) (n = 15) were prepared using a metallic mold. Composite resins were injected into the metallic mold, which was then placed on a glass plate lined with Mylar strip. The mold was slightly overfilled with composite resins, and then covered by another glass plate lined with a Mylar strip. A slight force was then applied on the glass plate using a finger, to flush out excess materials and create a smooth surface. The specimens were cured using a visible light-curing unit (Elipar Freelight 2, 3M ESPE, Germany) in accordance with the manufacturer instructions. After polymerization, the composite discs were removed from the mold and stored in deionized water for 21 days, to allow for the leaching of unpolymerized resin, and to ensure equal water uptake. Thereafter, the discs were polished using Flexi snap kit abrasive discs (Edenta AG, Hauptstrasse, Switzerland) in sequences of coarse to superfine. All the specimens were set in a desiccator for 24h before test procedures.

Preparation of artificial saliva

The artificial saliva used in the study was prepared with inorganic ion concentrations that were similar to those of saliva. The inorganic ion composition of the artificial saliva was as follows: 0.002g of ascorbic acid, 0.030g of glucose, 0.580g of NaCl, 0.170g of $CaCl_2$, 0.160g of NH_4Cl, 1.270g of KCl, 0.160g of NaSCN, 0.330g of KH_2PO_4, 0.200g of urea, 0.340g of Na_2HPO_4, and 2.700g of mucin in 1 L of distilled water. The solution was further titrated with a phosphate buffer that consisted of 26.4 ml of 0.06 M $Na_2HPO_4 2H_2O$ and 7.36 ml of 0.06 M KH_2PO_4. After titration, the pH of the artificial saliva solution was determined to be 7.5 [16,17].

Preparation of Arabic coffee

In this study, Nescafe Arabiana (NESCAFÉ® ARABIANA, South Korea) coffee was used as the staining solution. The ingredients of this coffee, as claimed by the manufacturer, are as follows: instant coffee, coffee creamer, corn syrup, palm oil, casein (contains milk) stabilizers (E340ii, E452ii), anti-caking agent (E551), emulsifiers (E481; E472, plant origin), acidity regulator (E524), natural cardamom flavor, natural biscuit flavor, natural spices flavor, and green tea extract. The coffee was prepared by emptying one sachet of the powder into 100 ml of hot water (80°C) with stirring.

Microhardness testing

The microhardness of the composite materials was measured using a microhardness tester (Micromet Buehler, Lack Bluff Illinois, USA), as shown in figure 1a. The specimens were placed on the stage of the microscope, and a 10× magnification was used to focus and adjust the smooth surface of resin discs without voids and irregularities, to create the indentation. A load of 2.942N was applied to the surface of each specimen for 30s. The lever on the hardness tester was activated by pushing it down; which caused the indenter to apply a force on the composite disc, thus creating a diamond-shaped indent. The indentation was made only on the top surface in three different areas. The average of the three readings was taken, and the microhardness values were calculated.

Measurement of color stability

The colors of the composite resin discs were assessed in the Commission Internationale de l'Eclairege L*a*b* (CIELAB) (Figure 1b) color space against a white background using a Color Eye 7000 spectrophotometer (Gretag Macbetch, New Windsor, New York, USA). The CIE L*a*b* color system is a chromatic value color space that measures the value and chroma with respect to L*a*b* coordinates: L* measures the lightness of the color from black (L* = 0) to white (L* = 100) (a value of 100 corresponds to perfect white, and that of 0 to black); a* indicates the color in the red (a* > 0) and green (a* < 0) dimensions; and b* indicates the colors in the yellow (b* > 0) and blue (b* < 0) dimensions. Three measurements were carried out for each specimen, and the mean corresponded to the CIELAB values. The total color differences (ΔEab*) were calculated as follows:

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

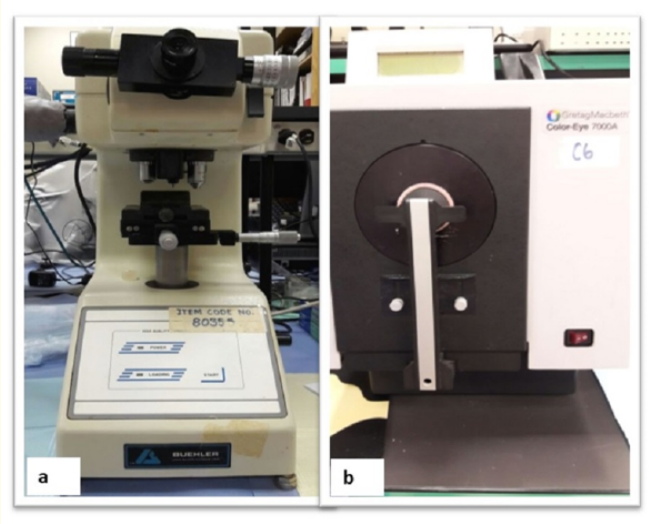

Figure 1: *(a) Microhardness tester and (b) spectrophotometer.*

Staining procedure

The staining process in this study was in accordance with that of a previous study [18]. The fifteen specimens from each group were randomly grouped into five specimens according to the three immersion solutions to be used. The composite discs were immersed in the artificial saliva (control group), Arabic coffee, and Coca Cola solution (Figure 2) at room temperature over a 28-day test period.

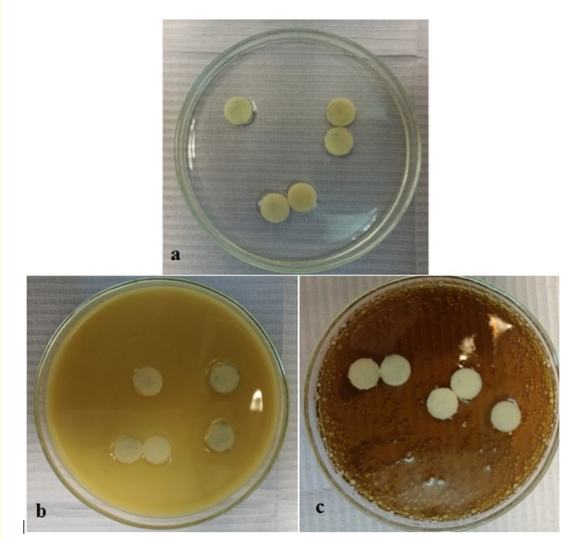

Figure 2: *The composite discs immersed in the staining solutions: a) Artificial saliva, b) Arabic coffee, and c) Coca Cola.*

The specimens were immersed for one hour, twice a day, in a closed petri dish; to prevent the evaporation of the staining solutions. The staining solution was freshly prepared every day prior to the immersion procedure. After each immersion cycle, the composite discs were thoroughly cleaned using a manual soft toothbrush, to remove any stains adsorbed onto the composite disc surface. The cleaned discs were stored in deionized water for the remainder of the time. For the microhardness and color analyses, the specimens were removed, dried using a blotted paper, and the testing was then carried out. The microhardness and color measurements at the baseline and after 7, 14, 21, and 28 days were recorded. The artificial saliva was changed every day. Moreover, the Arabic coffee was freshly prepared prior to immersion procedure, and a fresh can of Coca Cola was used each day for the immersion procedure.

Statistical analysis

The data obtained were analyzed using the Statistical Package for Social Sciences (SPSS) v 18.0 (SPSS Inc., Chicago, IL, USA). The descriptive statistics included the mean and standard deviation, in addition to the minimum and maximum values. The mean values of each group were analyzed by repeated measurements to test the significance in each group. The multiple comparisons of the mean values were tested using a Scheffe *post hoc* analysis. The significance level for all the statistical testing was determined at p value < 0 .05.

Results

Microhardness (H) test result

The analyzed data revealed that there was a significant difference in the hardness values among the three brands of composite resins. The highest hardness value was observed in the Grandio followed by Filtek Z350, and the least hardness was for the Filtek Bulk Fill ($p < 0.05$), as shown in table 2.

Composites (I)	Mean (SD)	Composites (J)	Mean (SD)	Mean Difference (I-J)	Std. Error	Sig.*
Filtek Z350	72.13 (2.10)	Filtek Bulkfill	53.19 (1.83)	19.02	.610	.000
		Grandio	96.60 (1.51)	-23.14	.610	.000
Filtek Bulkfill	53.19 (1.83)	Filtek Z350	72.13 (2.10)	-19.02	.610	.000
		Grandio	96.60 (1.51)	-42.16	.610	.000
Grandio	96.60 (1.51)	Filtek Z350	72.13 (2.10)	23.14	.610	.000
		Filtek Bulkfill	53.19 (1.83)	42.16	.610	.000

Table 2: *Comparison of hardness values between nanocomposite groups before immersion in the staining solutions.*

****:*** *The mean difference is significant at the .05 level.*

The descriptive statistics of the analyzed hardness measurement values of the three brands of composites stored in different mediums for different immersion times are presented in table 3.

The mean and standard deviation of the hardness values at the baseline and after 28 days of immersion in staining solutions are presented in table 4. The analysis of variance and Tukey *post hoc* analysis revealed that the composite specimen stored in the coffee and cola showed a decrease in the hardness values. However, the specimens stored in the saliva (control) showed an increase in the hardness values of the composite resins after 28 days of immersion. All the three groups of composite resins stored in saliva stored in artificial saliva showed an increase in the hardness values, which was not statistically significant. The three groups of specimens stored in Arabic coffee showed decreased values, which were not statistically significant ($p > 0.05$). The Filtek Z350 stored in cola showed decreased hardness values, which were not statistically significant. The other two groups, namely, the Filtek Bulk Fill and Grandio specimens demonstrated statistically significant values from baseline to 28 days of storage ($p < 0.05$).

Immersion Time	Composites	Staining solutions	Mean	Std. Error	95% Confidence interval	
					Lower Bound	Upper Bound
Baseline	Filtek Z350	Saliva	72.49	.831	70.81	74.18
		Coffee	72.09	.831	70.41	73.78
		Cola	72.06	.831	70.37	73.75
	Filtek Bulkfill	Saliva	53.04	.831	51.35	54.72
		Coffee	53.66	.831	51.97	55.34
		Cola	55.32	.831	53.63	57.01
	Grandio	Saliva	97.57	.831	95.88	99.25
		Coffee	97.68	.831	95.99	99.37
		Cola	96.07	.831	94.38	97.75
7 days	Filtek Z350	Saliva	72.63	.708	71.19	74.06
		Coffee	72.01	.708	70.57	73.44
		Cola	71.10	.708	69.67	72.54
	Filtek Bulkfill	Saliva	53.85	.708	52.41	55.28
		Coffee	53.87	.708	52.43	55.30
		Cola	52.52	.708	51.08	53.95
	Grandio	Saliva	98.27	.708	96.84	99.71
		Coffee	97.02	.708	95.58	98.45
		Cola	93.00	.708	91.57	94.44
14 days	Filtek Z350	Saliva	73.79	.845	72.08	75.50
		Coffee	72.17	.845	70.45	73.88
		Cola	69.89	.845	68.17	71.60
	Filtek Bulkfill	Saliva	54.84	.845	53.13	56.56
		Coffee	54.25	.845	52.54	55.96
		Cola	49.46	.845	47.74	51.17
	Grandio	Saliva	98.97	.845	97.26	100.68
		Coffee	96.11	.845	94.40	97.82
		Cola	90.44	.845	88.72	92.15
21 days	Filtek Z350	Saliva	75.29	1.063	73.13	77.44
		Coffee	72.23	1.063	70.07	74.38
		Cola	68.82	1.063	66.66	70.98
	Filtek Bulkfill	Saliva	56.20	1.063	54.04	58.35
		Coffee	54.47	1.063	52.31	56.63
		Cola	46.73	1.063	44.58	48.89
	Grandio	Saliva	99.56	1.063	97.40	101.71
		Coffee	94.92	1.063	92.77	97.08
		Cola	88.33	1.063	86.17	90.48
28 days	Filtek Z350	Saliva	76.59	1.183	74.19	78.99
		Coffee	72.28	1.183	69.88	74.68
		Cola	67.95	1.183	65.55	70.35
	Filtek Bulkfill	Saliva	57.27	1.183	54.87	59.67
		Coffee	55.87	1.183	53.47	58.27
		Cola	44.66	1.183	42.26	47.06
	Grandio	Saliva	100.24	1.183	97.84	102.64
		Coffee	94.24	1.183	91.84	96.64
		Cola	86.13	1.183	83.73	88.53

Table 3: *Descriptive statistics of analyzed hardness measurements of the composites stored in different staining solutions for different immersion times (n = 15).*

Type of composite and Immersion time	Mean (SD) Hardness values		
	Artificial Saliva (n = 5)	Arabic coffee (n = 5)	Coca cola (n = 5)
Filtek Z350			
Baseline	72.49 (2.07)	72.09 (2.13)	72.06 (2.12)
28 days	76.59 (3.34)	72.28 (2.38)	67.95 (1.30)
Filtek Bulk Fill			
Baseline	53.04 (2.44)	53.66 (1.14)	55.32 (1.92)
28 days	57.27 (1.87)	55.87 (3.63)	44.66 (4.15)*
Grandio			
Baseline	97.57 (1.81)	97.68 (1.14)	96.07 (1.58)
28 days	100.24 (3.11)	94.24 (2.58)	86.13 (4.06)*

Table 4: *Comparison of hardness values of the composites at baseline and after 28 days of immersion in staining solutions.*
**: Indicates statistically significant values within the group (p < 0.05)*

Color (ΔEab) measurement test results

The Color (ΔEab) measurement values of the three types of composites were analyzed, and the data are presented in table 5. The analyzed data revealed that there were differences in the color values among the three types of composite resins. The ΔEab values were 1.29 + 0.06, 0.99 + 0.03, and 0.97 + 0.03 for Filtek Z350, Filtek Bulk Fill, and Grandio, respectively. The ΔEab values for Filtek Z350 were significantly different (P < 0.05) when compared with the Filtek Bulk Fill and Grandio composites; however, no significant differences were observed between the Filtek Bulk Fill and Grandio composites (p > 0.05).

Composites (I)	Mean (SD)	Composites (J)	Mean (SD)	Mean Difference (I - J)	Std. Error	Sig.*
Filtek Z350	1.29 (0.06)	Filtek Bulkfill	0.99 (0.03)	.226	.027	.000
		Grandio	0.97 (0.03)	.466	.027	.000
Filtek Bulkfill	0.99 (0.03)	Filtek Z350	1.29 (0.06)	-.226	.027	.000
		Grandio	0.97 (0.03)	.240	.027	.237
Grandio	0.97 (0.03)	Filtek Z350	1.29 (0.06)	-.466	.027	.000
		Filtek Bulkfill	0.99 (0.03)	-.240	.027	.221

Table 5: *Comparison of color measurement values of the nanocomposite groups before immersion in the staining solutions.*
**: The mean difference is significant at the .05 level.*

The descriptive statistics of the analyzed color measurement values of the three types of composites stored in staining solutions and measured at different time-periods are presented in table 6.

The mean and standard deviation of the color measurement values at baseline and after 28 days of immersion in staining solutions are presented in table 7. The analysis of variance and Tukey *post hoc* analysis revealed that the composite specimen stored in the coffee and cola exhibited statistically significantly values from baseline to 28 days of immersion (p < 0.05) in all the composites groups. However, the specimens stored in saliva (control) showed a very minimal increase in the color measurement values of the composite resins after 28

Immersion time		Composites	Staining solutions	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound	
Dimension	Baseline	Filtek Z350	Saliva	1.240	.024	1.192	1.288
			Cofee	1.276	.024	1.228	1.324
			Cola	1.378	.024	1.330	1.426
		Filtek bulk fill	Saliva	.882	.024	.834	.930
			Cofee	.956	.024	.908	1.004
			Cola	1.352	.024	1.304	1.400
		Grandio	Saliva	.984	.024	.936	1.032
			Cofee	.934	.024	.886	.982
			Cola	1.006	.024	.958	1.054
	7 days	Filtek Z350	Saliva	1.264	.034	1.196	1.332
			Cofee	1.566	.034	1.498	1.634
			Cola	1.976	.034	1.908	2.044
		Filtek bulk fill	Saliva	.900	.034	.832	.968
			Cofee	1.392	.034	1.324	1.460
			Cola	1.842	.034	1.774	1.910
		Grandio	Saliva	1.004	.034	.936	1.072
			Cofee	1.306	.034	1.238	1.374
			Cola	1.382	.034	1.314	1.450
	14 days	Filtek Z350	Saliva	1.292	.046	1.198	1.386
			Cofee	1.832	.046	1.738	1.926
			Cola	2.858	.046	2.764	2.952
		Filtek bulk fill	Saliva	.918	.046	.824	1.012
			Cofee	1.718	.046	1.624	1.812
			Cola	2.706	.046	2.612	2.800
		Grandio	Saliva	1.020	.046	.926	1.114
			Cofee	1.536	.046	1.442	1.630
			Cola	1.904	.046	1.810	1.998
	21days	Filtek Z350	Saliva	1.316	.079	1.155	1.477
			Cofee	2.106	.079	1.945	2.267
			Cola	3.742	.079	3.581	3.903
		Filtek bulk fill	Saliva	.934	.079	.773	1.095
			Cofee	2.030	.079	1.869	2.191
			Cola	3.294	.079	3.133	3.455
		Grandio	Saliva	1.058	.079	.897	1.219
			Cofee	1.710	.079	1.549	1.871
			Cola	2.750	.079	2.589	2.911
	28 days	Filtek Z350	Saliva	1.384	.044	1.295	1.473
			Cofee	2.408	.044	2.319	2.497
			Cola	4.194	.044	4.105	4.283
		Filtek bulk fill	Saliva	.954	.044	.865	1.043
			Cofee	2.368	.044	2.279	2.457
			Cola	4.198	.044	4.109	4.287
		Grandio	Saliva	1.096	.044	1.007	1.185
			Cofee	1.880	.044	1.791	1.969
			Cola	3.274	.044	3.185	3.363

Table 6: *Descriptive statistics of the analyzed color measurements of composites stored in different staining solutions for different immersion times (n = 15).*

Type of composite and Immersion time	Mean (SD) ΔEab values calculated with respect to of L*a*b* Values		
	Artificial Saliva (n = 5)	Arabic coffee (n = 5)	Coca cola (n = 5)
Filtek Z350			
Baseline	1.24 (0.11)	1.27 (0.05)	1.37 (0.03)
28 days	1.38 (0.09)	2.40 (0.08)*	4.17 (0.12)*
Filtek Bulk Fill			
Baseline	0.88 (0.03)	0.95 (0.02)	1.15 (0.05)
28 days	0.95 (0.01)	2.36 (0.13)*	4.19 (0.07)*
Grandio			
Baseline	0.98 (0.05)	0.93 (0.01)	1.0 (0.02)
28 days	1.09 (0.06)	1.18 (0.06)*	2.0 3.27 (0.15)*

Table 7: *Comparison of color measurement values of the nanocomposite groups after immersion in the staining solutions.*
**: Statistically significant values within the group (p < 0.05).*

days of immersion, which was not statistically significant (p > 0.05). The color measurement values of the Filtek Z350 (4.17 + 0.12) and Filtek Bulk Fill (4.19 + 0.07) composites stored in cola for 28 days showed the highest difference in color values from the baseline when compared with the specimens in other groups.

Discussion

In this *in-vitro* study, the color stability of the composite resin specimens was measured at baseline (24h), 7 days, 14 days, 21 days and after 28 days immersion in three different solutions (artificial saliva, Arabic coffee, and cola). Different *in vitro* studies demonstrated that common food substances such as coffee, cola, or red wine may have a significant influence on the surface colors of composite resins [19]. Hence, in this study, artificial saliva, cola and Arabic coffee were used to investigate the effects of these solutions on the color stability of nanocomposite restorative materials.

The esthetic restorative materials in the oral cavity are continuously exposed to various beverages, food colorants, and saliva. Hence, it is necessary to investigate the effect of such exposure on the color stability of the restorative materials. For the evaluation of the color stability of restorative composites, the color changes of the materials exposed to staining solutions over a long duration are required, for the simulation of clinical conditions [20]. However, under the laboratory conditions, several simulations tests were used to simulate the oral aging conditions, for the determination of the color stability of the composite [14].

The color stability of the restorative materials can be evaluated using either visual assessment or devices such as a digital spectrophotometer [21]. Color is a complex phenomenon affected by several factors such as the lighting conditions, light scattering, translucency of the materials, opacity, and the human eye; which has an influence on the overall perception of the color of a material. To reduce the effect of such influencing factors, the spectrophotometer plays an important role in assessing the color and the elimination of unwanted errors [22]. The spectrophotometric color analysis is a recommended method for dental purpose, as it is more suitable for the assessment of slight color changes, which is similar to the case of restorative materials. In addition, it offers the advantages of repeatability, sensitivity, and objectivity [23]. This justifies the use of a spectrophotometer and the CIE Lab coordinate system in assessing the color stability of the nanocomposites in this study.

It has been reported that composite resins can absorb water and other fluids with pigments, resulting in staining. It is expected that water acts as a medium for penetration of stains into the resin matrix. Hence, water sorption is directly related to the amount of resin

matrix present in the composite resin. The glass filler particles do not show any tendency to absorb water. Accordingly, higher the percentage of resin matrix, greater is the water sorption by the composites. It was reported in several studies that composite resins with a lower percentage of inorganic fillers exhibited more significant color changes due to the presence of a greater volume of resin matrix, which allowed for greater water sorption [24,25].

Previous studies reported that ΔE values ranging from 1 to 3 are perceptible by the naked eye and ΔE values greater than the critical value of 3.3 are clinically unacceptable [26,27]. In this study, all the specimens stored in the solutions demonstrated color changes; however, the Filtek Z350 and Filtek Bulk Fill composite specimens stored in cola showed values greater than the critical value. This outcome is not in agreement with the findings of Poggio., *et al.* who concluded that cola does not have an influence on the color of esthetic restorative materials [28]. The specimens stored in coffee showed lower values when compared with the specimens in cola, which is contradictory with the findings of a previous study; wherein it was concluded that coffee results in more color changes than cola [29,30]. The results of this study are in accordance with the findings of Fontes., *et al.* who concluded that coffee does not result in visible color changes [31]. The most significant finding in our study was that the control group and specimens stored in saliva did not maintain their colors over the 28-day immersion period. In addition, minor color changes were observed. This confirms that saliva may also have an influence the color stability of resin nanocomposites. Furthermore, the color changes are not only due to the staining solutions but also could be due to resin matrix composition, the method of light activation and composite finishing procedure as demonstrated by previous studies [14,28,31].

Hardness is directly related to other physical properties of composite resins such as mechanical strength and rigidity, and resistance to intra-oral softening, in addition to the degree of conversion (DC%) [32]. The decreased hardness value of a composite indicates a poor chemical or physical bonding between the resin matrix and filler interface [33]. It has been reported that saliva, diet, and beverages may have an influence on the hardness of resin-composites [34,35]. Moreover, it was found that different beverages such as coffee, tea, and cola can reduce the hardness of the composites [35].

In this study, there were changes in the hardness values among the three types of composite resin exposed to different staining solutions after a period of 28 days. All the three composite groups stored in artificial saliva showed an increased hardness values, whereas the specimens stored in coffee and coal showed a decreased hardness values. However, no significant changes were observed in the decreased hardness values of the specimens stored in coffee, whereas the Filtek Bulk Fill and Grandio composite specimens stored in cola exhibited a significant decrease in their hardness values. This is in agreement with the findings of Yanikoglu., *et al.* who concluded that coffee and cola decrease the hardness of the composites [35]. It should be noted that the Grandio composite resin, which contained 87 wt% of filler, exhibited a significant decrease in hardness values after immersion in cola for 28 days.

In a similar study by Karaman., *et al.* the microhardness of silorane- and methacrylate-based resin composites were evaluated. As reported, the microhardness was significantly reduced in specimens immersed in coffee rather than cola, which is not in agreement with the results of this study [36]. Moreover, the findings of this study were in agreement with the study by Awliya., *et al.* where it was reported that no significant changes in the microhardness values of the tested composite resins stained with different coffee solutions over a period of three weeks were observed [37].

All the composite specimens stored in artificial saliva exhibited an increase in hardness values, which is in good agreement with the findings of a previous report; which concluded that the nanocomposite stored in artificial saliva showed the highest hardness values [37].

Accordingly, this study demonstrates that Arabic coffee has a less significant influence on the color and hardness values of composite resins when compared with the findings of other studies, wherein different types of coffee solutions were used, and significant differences in the tested parameters were found [36,37]. Based on the results of this study, the hypothesis was partially accepted as only the specimens in cola solution demonstrated significant changes with respect to color stability and hardness.

Conclusion

Within the limitations of the study, it can be concluded that all the specimens stored in saliva showed minor color changes and increased hardness values. The specimens immersed in cola demonstrated significant color changes, especially the Filtek Z350 and Filtek Bulk fill composite resins. Furthermore, the Filtek Bulk Fill and Grandio composite materials showed significant decrease in hardness values after immersion in Coca-Cola solution for 28 days.

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Volume 19 Issue 1 January 2020