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Influence of Energy and Soft Drinks on the Surface and Mechanical Properties of Nanofilled Composite Resin

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Abstract Aim: To evaluate the effect of energy drinks (Redbull and Bison) and soft drinks (CocaCola and 7 Up) on the surface roughness (SR) and microhardness (MH) of Filtek Z350 nanofilled composite resin. Materials and methods: A total of 60 disk-shaped specimens were prepared from Filtek Z350 XT restorative material and randomly allocated to 5 groups (n=12). The specimens were stored in petri dish containing Redbull (Group 1); Bison (Group 2); Coca-Cola (Group 3); 7 Up (Group 4) and distilled water (Group 5/Control). The SR and hardness of the composite specimens were determined after 24 hours (n=6) and 28 d (n=6) of storage in energy and soft drinks. SR (in Ra) was measured using a non-contact optical profilometer and MH (VHN) was tested using hardness tester equipped with a Vickers diamond indenter. The data obtained was analyzed using SPSS v.20 statistical analysis software. The data was analyzed using Wilcoxon sign rank test. A $P < 0.05$ was considered as statistically significant. Result: Group Redbull showed maximum SR at 28 days (0.30 ± 0.11) followed by Bison at 28 days (0.21 ± 0.09). MH test results showed specimens in distilled water with increased MH at 24 hours (114 ± 9.4). The least MH was seen in Redbull (85 ± 12.3) at 28 days. Conclusion: The energy drinks have a substantially damaging effect on SR and MH compared to soft drinks and distilled water; and these effects are increased with duration of exposure.

Keywords: *resin composites, nanocomposite, surface roughness (SR), microhardness (MH), energy drinks, soft drink*

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1. Introduction

Dental restorative materials are not only supposed to possess extended robustness and stability in dynamic oral conditions [1] but also the aesthetics. Hence, the focus of the investigators in recent years has been to improve the physical and the mechanical properties of the aesthetic restorative materials, i.e., dental composite materials. The clinical practice of resin-based restorative materials has increased drastically because of their good aesthetic, handling properties, and ability to adhere with dental hard tissue [2].

With the advancement in filler and polymer technology, aesthetic dental composites with filler sizes range from nano to macro in combinations with different resin polymers are available in the market [3,4]. The available data shows that the physical and mechanical properties of composite restorative materials are affected by filler weight content and sizes also [5-7]. The recent development of new composite restorative materials known as "nanofilled" have diminished particle size and higher filler loading, resulting in enhanced optical and mechanical properties [8,9]. Nanofilled restorative material contains nanomers and nanoclusters of zirconia/silica in the range of 5-75 nm and 0.6-1.4 µm, respectively [10].

Over the last few years, the use of acidic energy beverages and carbonated soft drinks has been well-liked among the new generations [11]. Dental composite is a material of choice for direct restorations [12]. Despite an improvement in composition and characteristics of dental nano-filled composites, these materials behave differently due to the adverse oral environment due to change in temperature, pH and dietary acidic contents.

Acidic erosion has clinical significance, because of acidic drinks, degradation and aging of dental composites occur. Dental composites' satisfactory clinical life is mainly ascertained by their resistance to deterioration in the oral environment [11]. Biodegradation affects the physical and mechanical properties of the composites.

Hardness is an important surface property for any restorative material [13]. Hardness can be a suitable estimate of the clinical life of a composite material. Similarly, the SR of composite material is an important parameter to gauge the clinical longevity and aesthetics of restorative material [11]. Rough surface on a dental restoration can predispose to an accumulation of plaque, residues, and stains leading to gingival irritation, secondary caries, diminished gloss and discoloration of the restoration [14].

Therefore, this study was aimed to evaluate the deleterious effect of energy and soft drinks on the important properties of dental composites such as MH and SR using a commercially available nano-filled composite restorative material. It was hypothesized that energy and soft drinks too would have deleterious effects on new generation dental composite also.

2. Materials and Methods

Table 1 present the restorative composite material used in this study, and the energy and soft drinks with their composition.

A total of 60 flat circular disks measuring 6.0 mm in diameter and 3.0 mm in thickness were fabricated using Filtek Z350 XT nanocomposite. A round metallic mold was placed over the glass slide and composite resin material was packed into the mold. Another glass slide was placed on the top of the mold and pressed to remove excess composite material. The samples were light cured of both the top and bottom surfaces using light curing unit (Acteon Mini, Bordeaux, France) with light intensity of 550 W/cm2. The light curing unit was firmly held 1.0 mm above the glass slide for 40 s to polymerize the dental composite discs. Next, the specimens were gently removed from the mold and polished with Soft-lex abrasive discs to obtain a smooth clinical finish. The abrasive discs were used in the order of their particle size (Coarse-medium-fine-ultrafine). Subsequently, the polished specimens were stored in distilled water for 24 h before storage in energy and soft drinks. After 24 hours, the specimens were removed from distilled water, dried and were randomly allocated into 5 groups (n=12) and their subgroups (n=6) according to storage conditions and the time mentioned in the flow chart.

Table 1. Restorative composite material and different beverages with their composition used in this study

Name	Composition	Manufacturer
Filtek Z350 XT Universal Nanocomposite A2 Shade	**Organic matrix:** Bisphenol A-glycidylmethacrylate (Bis-GMA), Urethane dimethacrylate (UDMA), Triethylene glycoldimethacrylate (TEGDMA), Bisphenol A ethoxylate Dimethacrylates (BIS-EMA) **Inorganic fillers:** Silica, zirconia, zirconia/silica aggregated	3M ESPE Dental Products, Seefeld, Germany
Redbull Energy drink	Sucrose, glucose, acidity regulatory sodium, caffeine, vitamins, natural flavors, colors	Red Bull GmbH, Fuschl am See Austria
Bison Energy drink	Carbonated, water, sugar, citric acid, caffeine, sodium benzoate, vitamins, natural flavors, colors	Abuljadayel Beverages INC, Jeddah, Saudi Arabia
7up Soft drink	Filtered carbonated water, sugar, natural flavors, citric acid, potassium citrate, potassium benzoate, aspartame, acesulfame potassium, calcium disodium, EDTA.	PepsiCo, Saudi Arabia
Coca-Cola Soft drink	Carbonated water, Sugar, Caffeine, Phosphoric acid, Caramel color, Natural flavorings	The Coca-Cola Company, Saudi Arabia
Distilled water		Riyadh, Saudi Arabia

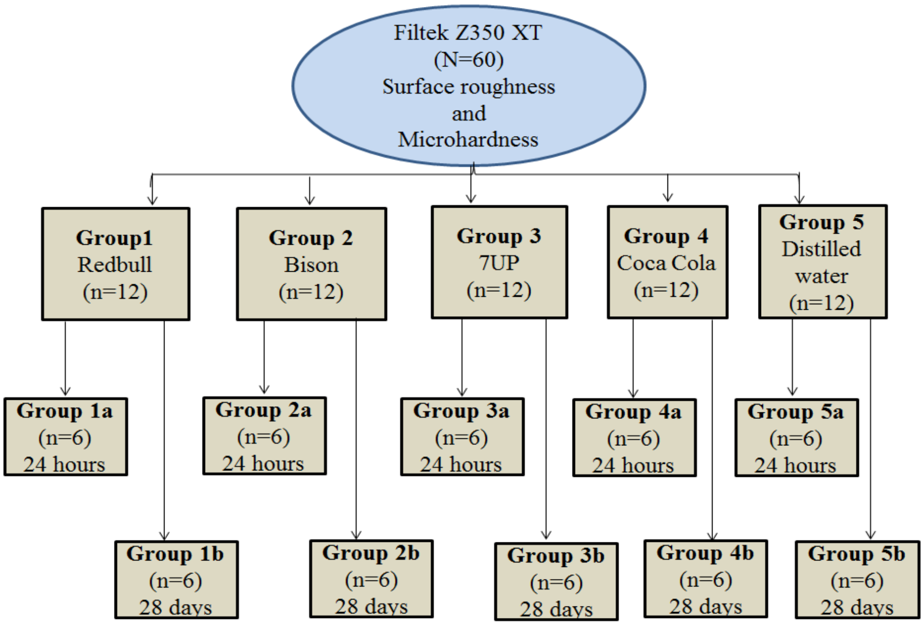

Figure 1. Flowchart illustrating the groups, surface treatment and their characterization methods

The control specimens (of group 5) were stored in distilled water. However, the specimens in the experimental groups were immersed for 5 min; three times daily in respective beverages. This immersion procedure represented a medium frequency of beverage intake. An adequate quantity of solutions (25ml) was maintained in petri dish in all the groups during the immersion period. The beverages in all the groups were regularly changed every 24 hours until the conclusion of the immersion regimen. After exposing to respective beverages, the specimens of the experimental groups were stored in distilled water at room temperature between immersions. The specimens removed from the beverages were cleansed using distilled water to remove any remnants from the surface. The cleaned composite discs were dried using absorbent paper and underwent SR and MH measurements.

2.1. Surface Roughness (SR) Measurement

SR of composite discs was assessed using a 3D optical non-contact surface profilometer (Bruker Contour GT, Tucson, AZ, USA). The device is bench mounted with an automated and programmable turret with X, Y, Z movements. The specimens were randomly scanned for SR at five different areas covering the entire specimen dimension. The mean of the five measurements represented the roughness value for that particular specimen (Ra). The measurements were numerically calculated by the Vision 64 software.

2.2. Microhardness (MH) Measurement

The MH of the specimens were evaluated using MH tester (INNOVA TEST, Borgharenweg, Maastricht, Netherlands) equipped with diamond, square-head indenter. The specimens were placed on the specimen holder of the device and a 10x magnification was used to focus flat surface on composite discs before indentation. A load of 500 g was applied to the surface of each specimen with a dwell time of 15 sec and the indent formed on the disc was recorded by the software connected to the device. The indentation was made on the top surface of the specimen at three random areas and the mean of them represented the hardness value of that particular specimen.

2.3. Scanning Electron Microscopy (SEM) Evaluation

Respective specimen from each group was analyzed to visual evaluation. The SEM micrographs were taken using a scanning electron microscope (Jeol JSM-5900 LV SEM, Tokyo, Japan) operating at 10 kV with 300X magnification.

2.4. Statistical Analysis

All the data collected were statistically analyzed using the Statistical Package for Social Sciences (SPSS) v 20.0 (SPSS, Chicago, IL). The data were analyzed using the Wilcoxon sign rank test. Kruskal-Wallis was applied to find out the statistical difference concerning to SR and MH among all the groups at 24 h and 28 d. A $P < 0.05$ was considered as statistically significant.

3. Results

Table 2 presents The Wilcoxon Signed-Rank Test showing a significant difference in SR at 24 h and 28 d with respect to all the groups (P< 0.05). The highest SR was observed in group 1 at 28 d (0.30 ± 0.11 µm). The lowest was observed in group 1 at 24 h (0.14 ± 0.08 µm). The Kruskal-Wallis test for SR (Table 3) showed a highly significant difference among all the groups at 24 h and 28 d (P=.000).

Table 2. Comparison of the mean of surface roughness (Ra, in µm) using Wilcoxon sign rank test

Groups	Immersion time	Mean	S.D	*P* value
Group 1/Redbull	24 h	.141	.08	0.014*
	28 d	.300	.11	
Group 2/Bison	24 h	.142	.07	0.019*
	28 d	.210	.09	
Group 3/7 Up	24 h	.142	.08	0.034*
	28 d	.189	.08	
Group 4/Coca-Cola	24 h	.143	.06	0.024*
	28 d	.191	.07	
Group 5/Distilled water	24 h	.146	.10	0.09
	28 d	.151	.15	

*significant.

Table 3. Comparison of surface roughness of the study groups using Kruskal-Wallis test

	24 Hrs	28 Days
Kruskal-Wallis	20.22	27.72
P value	0.00*	0.00*

*Significant.

Table 4 present Wilcoxon Signed-Rank Test showing significant difference in MH at 24 hours and 28 days with respect to all the groups ($P < 0.05$). The highest MH was observed in group 5 at 24 h (114 ± 9.4 VHN). The lowest MH was observed in group 1 at 28 d (85.0 ± 12.3 VHN). Kruskal-wallis test (Table 5) showed significant difference in microhardness values among all the groups at 24 hours and 28 days (P= .000).

Table 4. Comparison of the mean microhardness (in VHN) of the study groups using Wilcoxon sign rank test

Groups	Immersion time	Mean	S.D	*P* value
Group 1/Redbull	24 h	113.0	9.8	0.014*
	28 d	85.0	12.3	
Group 2/Bison	24 h	111.0	10.4	0.024*
	28 d	88.0	9.5	
Group 3/7 Up	24 h	114.0	6.9	0.037*
	28 d	96.0	4.7	
Group 4/Coca-Cola	24 h	113.0	8.8	0.041*
	28 d	93.0	5.8	
Group 5/Distilled water	24 h	114.0	9.4	0.08
	28 d	111.0	13.7	

*significant.

Table 5. Comparison of microhardness of the groups using Kruskal-Wallis

	24 Hrs	28 Days
Kruskal-Wallis	17.039	27.964
P value	.002*	.000*

*Significant.

Figure 2 displays the SEM micrographs of the randomly selected specimen from each group. The visual analysis of the micrographs further affirmed coarsely surface of Redbull specimen (Figure 2b) followed by Bison specimens (Figure 2c). Specimens in distilled water showed the least surface changes (Figure 2a).

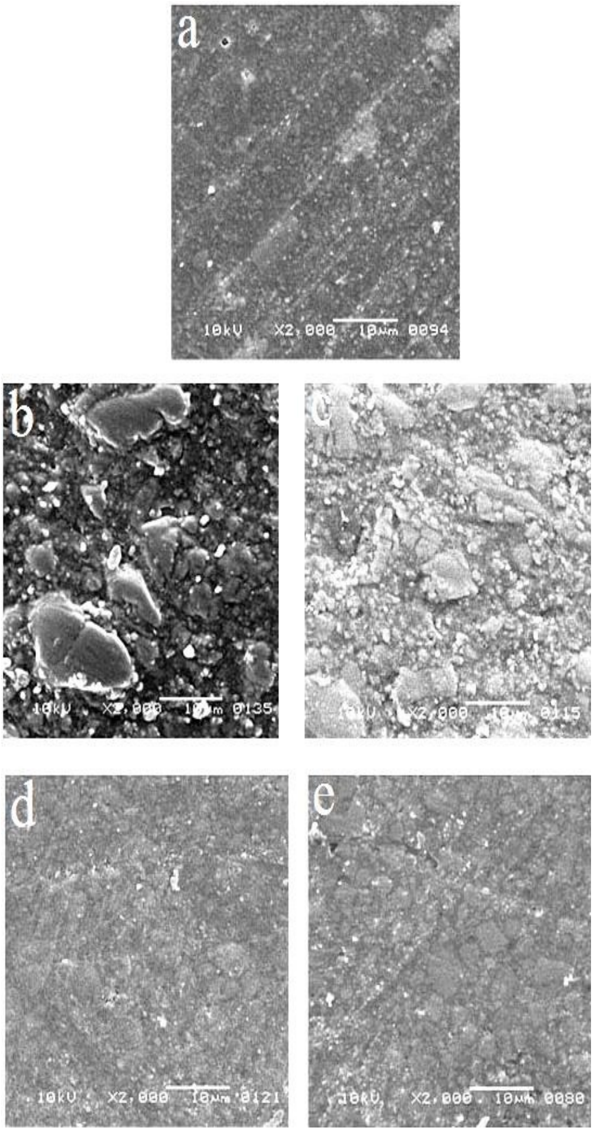

Figure 2. Scanning electron microscopic images of the representative specimen from the groups after 28 days of storage (a- Distilled water; b- Redbull; c- Bison; d- 7 Up; e- Coca-Cola)

4. Discussion

The present study evaluated nanofilled composites since they are clinicians' choice presently widely used due to their state of the art characteristic in terms of filler formulation [15]. The specimens in the present study were immersed for 5 min; three times daily in the energy and soft drinks. This immersion procedure represented a medium frequency of beverage intake and also the above immersion regimen was selected to simulate in-vivo conditions of the oral cavity, where the saliva dilutes the acidic concentration of beverages [16].

All composite disks demonstrated a significant increase in SR after immersion in their respective beverages. The increased SR of specimens stored in distilled water could be explained by the water uptake and polymer degradation of the resin matrix. However, an increased roughness among specimens of energy and soft drinks groups could be explained by the process of degradation and erosion occurring on the smooth composite surfaces over a while. The relatively soft resin matrix exposed to highly acidic beverages is leeched out preferentially leaving the filler particles protruding from the surface [16]. The mean SR values of the groups were lower than 0.2 µm except for specimens stored in Bison (0.21 µm) and Redbull (0.30 µm) for 28 d. The clinical threshold of bacteria adherence is 0.2 µm while a 0.3 µm change in surface roughness could be perceived by the patient's tongue [17]. Composite resins with SR values above the bacteria adherence threshold limit could negatively affect the composite resin's strength inside the oral cavity, thereby promoting secondary caries formation [18].

MH values of nanocomposite resin after 28 d of storage in distilled water was lower than the baseline (24 h) MH values. This outcome is not in agreement with the previous studies which demonstrated increased hardness values of the specimens stored in distilled water [9,19,20]. MH values of the 28 d storage groups showed lower surface hardness compared to baseline groups irrespective of the beverages used. This indicates that immersion time in the solutions has a significant influence on MH of the composite resin. This is explained by the deterioration of the materials due to liquid absorption. Water acts as a plasticizing molecule within the composite matrix softening the polymer resin component by swelling the network and dropping the frictional forces between polymeric chains [9,21]. Furthermore, composite resins are highly soluble in low pH solutions, and this can lead to matrix softening, surface abrasion and loss of structural ions. The acid in these beverages can penetrate into the resin matrix and accelerate the release of unreacted monomers. The ingredients used in these drinks, especially citric acid, is known to have a damaging effect on hardness of dental surfaces and resin-based restorative materials as also confirmed by previous studies [22,23].

There was a qualitative difference seen in the scanning electron microscope (SEM) micrographs of the specimens stored in energy and soft drinks. The surface was smoother on the nanofilled composite resin immersed in distilled water as compared to those specimens stored in soft drinks and energy drinks. The specimens immersed in soft drinks showed an irregular filler appearance whereas the specimens stored in energy drinks looked coarser and granulated than soft drinks specimens.

Despite the fact that this study could not completely simulate the complex oral environment, it substantiates the deleterious effects of commercially available energy and soft drinks on nanofilled composite materials which the patients should be informed of. The outcome of the present study demonstrated a significant increase in SR and reduction in MH of nanofilled composite due to the use of energy and soft drinks. Therefore, the null hypothesis that the energy drinks and soft drinks have no significant effect on SR and MH of the nanofilled composite resin was rejected.

In this study, only short-term evaluation of these beverages was performed; the effect could have been more damaging had the composite resin exposed for a long duration. The sample size was limited only to 6 specimens per group. The acidity or pH of the beverages used was not determined in the study. Future studies are recommended to evaluate the effect of energy and soft drinks on the color stability of nanocomposite resins. Also, it is recommended to study the effect of such beverages on the mechanical properties of nanocomposite resins. Within the limitations of this in-vitro study, the following conclusion has been drawn:

a) The energy drinks have a significant damaging effect on the SR and MH compared to soft drinks.

b) The effects are increased with duration of exposure thereby alarming those populations who frequently consume such drinks.

c) The composite resins demonstrated increased SR values and decreased MH values irrespective of the storage medium after 4 weeks of storage.

d) Redbull (among energy drinks) and Coca-Cola (among soft drinks) demonstrated an increased damaging effect.

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