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International Journal of Dentistry and Oral Health
ISSN 2378-7090 | Open Access

RESEARCH ARTICLE

Volume 7 - Issue 5

Effect of Energy Drinks on Color Stability of Different Restorative Materials

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Received: 17 May, 2021 | **Accepted:** 11 Jun, 2021 | **Published:** 17 Jun, 2021

Citation: AlSarheed M, Salama F (2021) Effect of Energy Drinks on Color Stability of Different Restorative Materials. Int J Dent Oral Health 7(5): dx.doi.org/10.16966/2378-7090.369

Abstract

Background: The purpose of this *in vitro* study was to evaluate the effect of finishing/polishing procedures on color stability of three restorative materials: Nano-hybrid resin composite (NRC), silver glass ionomer cement (SGI), and resin-modified glass ionomer cement (RMGI) exposed to different staining of energy drinks: Barbican, Bison, and Red bull.

Methods: Cylindrical specimens (9 mm × 2 mm) were prepared from three restorative materials (shade A2) used in pediatric dentistry. From each material, 40 specimens were prepared, finished and polished using the Sof-Lex™ system and then color was measured (Testing Phase One-T1). The specimens in each subgroup were exposed to different oral staining beverages and distilled water as control. The color measurement was repeated three times. The change in color of the specimens was measured by the color difference formula ΔE* which is the difference between final and initial values.

Results: All groups showed color changes after the application of energy drinks and distilled water with a statistically significant difference among the restorative materials and energy drinks ($P<0.05$). When discoloration of different materials is considered overall, the highest discoloration, which is the difference from baseline, was recorded for Medifil IX AC after application of Bison, for EsCom100 after application of distilled water, and for Medifil Silver after application of Red Bull. Multiple comparison tests showing correlations between different energy drinks and distilled water by the restorative materials at baseline and after application of energy drinks and distilled water.

Conclusion: The color difference ΔE* between final and initial values after exposure to different staining of energy drinks was unacceptable for all restorative materials tested with the exception of the resin composite.

Keywords: Energy drinks; Dental restorative materials; Color stability; Surface treatment

Background

The consumption of sports and energy drinks has gained high popularity among the adolescent population [1]. Although the purpose of those drinks is to enhance performance and endurance and prevent dehydration for individuals involved in physical activity, they are being widely consumed by the general population [2]. Previous studies have shown that these beverages potentially cause dental erosion and, due to their acidity, may be detrimental to the properties of restorative materials [3].

Dental esthetic is desired by both adolescents and parents, and the advent of tooth-colored restoratives material has been indispensable for this purpose. Even dentists prefer to use tooth-colored restorative materials, which have different physical properties, and shades compared to non-aesthetic restorative materials such as amalgam [4]. These restorative materials to be clinically successful are required to have long-term continuity, a quality which is strongly influenced not only by the intrinsic characteristics of the materials but also by the environment to which they are exposed [5]. A common problem encountered with these materials, after months and years of use and exposure to a variety of different food and liquid ingested by adolescents [6]. In addition, other factors such as low pH due to acidic foods and drinks may influence the material's mechanical and physical characteristics [7].

Resin composite, glass-ionomer, and resin-modified glass-ionomer are the best direct esthetic materials these days due to their improvement in mechanical properties, esthetic, and bonding [8]. Physical properties can be influenced by the chemical environment present in the mouth. The change in the oral environment that causes the staining can occur either intrinsically or extrinsically [9]. Intrinsically, color can change due to physiochemical alterations of the resin matrix. Color can also change extrinsically due to the absorption of stains on the outer surface [6]. Many new restorative materials have been developed, and the ability to prevent extrinsic and intrinsic stains of restorations has become an important challenge. Adolescents consume many beverages due to their daily diet; these drinks may affect their esthetic restorations [10]. Few studies evaluated the effect of energy drinks on esthetic direct dental materials commonly used for younger age [10,6]. Therefore, the purpose of this *in vitro* study was to evaluate the effect of finishing/polishing procedures on color stability of three restorative materials: Nano-hybrid resin composite (NRC), silver glass ionomer cement (SGI), and resin-modified glass ionomer cement (RMGI) exposed to different staining of energy drinks: Barbican, Bison, and Red bull. The null hypothesis was no difference in color stability of the finishing/polishing procedures of different restorative materials exposed to different staining of energy drinks.

Materials and Methods

This study was approved by the Ethical Committee of Human Studies, College of Dentistry Research Center, King Saud University (KSU) and granted by the Deanship of Research of KSU. A light-cured Nano-hybrid resin composite (EsCom100, Spident, Co, Ltd, Gojan-Dong, Korea), a Silver reinforced glass ionomer (Medifil Silver, Promedica Dental Material GmbH, Neumuenster, Germany,) and a glass ionomer (Medifil IX AC, Promedica Dental Material GmbH, Neumuenster, Germany) with all shade A2 shade were used. A total of 120 disc-shaped specimens (n=40 for each material), 9 mm in diameter and 2 mm thick, were prepared using a customized cylindrical metal mold. In order to obtain a flat polymerized surface without bubble formation, the specimens were covered on both sides (top and bottom) with a polyester matrix strip (Mylar Strip, Henry Schein, Melvilie, NY, USA) and a thin, rigid glass microscope slide (1-mm thick) (Shandon Polysine Slides, Thermo Scientific, Kalamazoo, Mich., USA) and pressure were applied on the slides to extrude the excess material. Where applicable the restorative materials were then polymerized through the glass slide and polyester matrix strip according to the manufacturer's recommendations, using a light cur unit LED (Elipar free Light 2, 3M ESPE, St Paul, MN, USA) operating in standard mode and emitting not less than 800 mW/cm^2, as measured with a light meter that was placed on the curing unit before beginning the polymerization. Afterward, all specimens were stored in distilled water in a lightproof container for 24 hours at 37°C. The top surfaces of all specimens were serially polished with a series of three grades (medium, fine, and super-fine) of Sof-Lex disks (3M ESPE, St. Paul, MN, USA) with a slow-speed hand-piece under dry conditions for 30 seconds for each specimen before color evaluation. The samples were randomly divided into 4 groups where every group consists of 10 specimens of each material. All specimens were stored in distilled water in a lightproof container for 24 hours at 37°C before measurement of the color (Testing Phase One-T1). The color was measured 3 times in the center of each specimen using a spectrophotometer (Color-Eye 7000, NY, USA) against a white background using LABCH relative to CIE standard illuminants D65, CWF, and C to measure ΔE (color difference) for SCI (Specular Component Included). All specimens according to the groups were then immersed in the energy drinks Barbican (based Bass Brewery, UK), Bison (Hayaloti Co. Ltd, Turkey) and Red bull 9 Red Bull GmbH, Austrian) or distilled water for 96 hours. Specimens were rinsed and prepared for color measurement (Testing Phase Two-T2) similar to the baseline measurement.

Statistical analysis

Two-way analysis of variance was used and tests the interaction between materials and media then one-way ANOVA was used to test the effect of material within each media and media within the material. Turkey multiple comparison tests used to pairwise comparison. Level of the significant set at 0.05 any p-value less than Two-way analysis of variance used and test the interaction between Material and media then one way ANOVA used to test the effect of material within each media and media within the material. Turkey multiple comparison tests used to pairwise comparison. Level of the significant set at 0.05 any p-value less than that considers significance.

Results

Table 1 presents color change values ΔE* of the restorative materials at baseline and after application of energy drinks and distilled water as control. All groups showed color changes after the application of energy drinks and distilled water with a statistically significant difference among the restorative materials and energy drinks ($P<0.05$). When discoloration of different materials is considered overall, the highest discoloration, which is the difference from baseline, was recorded for Medifil IX AC after application of Bison, for EsCom100 after application of distilled water, and for Medifil Silver after application of Red Bull. ΔE* decreased after the application of Red Bull for Medifil IX AC and after the application of Barbican, Bison, and Red Bull on EsCom100. The ΔE* increased after the application of Barbican, Bison, Red Bull, and distilled water on Medifil Silver. Multiple comparison tests showed correlations between different energy drinks and distilled water by the restorative materials at baseline and after application of energy drinks and distilled water (Table 1). Figure 1 showing the average ΔE* for each restorative material after the application of energy drinks and distilled water.

Discussion

The present study analyzed the colorimetric behavior of three restorative materials to evaluate whether different compositions influence color stability by considering the effect of different energy drinks and polishing systems. The null hypothesis was rejected, as there was a difference in color stability of the finishing/polishing procedures of different restorative materials exposed to different staining of energy drinks. Discoloration of restorative materials remains a major cause for their esthetic failure and this can be a reason for the replacement of restorations in esthetic zones. This process concerns both patients and dentists and consumes time and money [11]. Discoloration in restorative materials is multifactorial and it can be either intrinsic or extrinsic induced discoloration [10,12]. Resin matrix, filler loading, and photoinitiator systems have a direct impact on intrinsic color stability [13]. Such materials are susceptible to extrinsic staining; including plaque accumulation, superficial degradation, and surface stains due to adsorption of staining agents such as children beverages [14,15].

Color stability can be evaluated both visually and by using specific devices [16,17]. The methodology used in the present study is according to previous studies that used spectrophotometric analysis [16,17]. This system was chosen to evaluate color variation (ΔE*) because it is appropriate for small color changes determination and has advantages such as repeatability, sensitivity, and objectivity [18]. A spectrophotometer is used to measure resistance to staining effects which could be due to tea, coffee and juice and lower values indicate less staining [19]. In the present study, finishing and polishing processes may affect surface smoothness and could be related to early discoloration as rough surfaces collect surface stains more than smooth surfaces [20,21]. In addition, in the present study, all tested restorative materials were not equally susceptible to surface staining which may be related to their different composition. This explains the differences observed between these materials in this investigation. Ideally, restorative materials should not change in color or appearance, but a degree of color change can be caused by a number of factors, including incomplete polymerization, water sorption, chemical reactivity, oral

Table 1: Color change values (ΔE*) of the tested restorative materials at baseline and after application of the energy drinks.

Restorative Material	Energy Drinks and Control	Time	Mean	Std. Error	95% Confidence Interval		P-value
					Lower Bound	Upper Bound	
Medifil IX AC	Distilled Water	Baseline	1.291	0.143	1.009	1.573	0.475
		After application	1.431	0.243	0.953	1.909	
	Barbican	Baseline	2.148	0.143	1.866	2.430	0.806
		After application	2.212	0.243	1.734	2.691	
	Bison	Baseline	2.197	0.143	1.915	2.479	0.0001
		After application	5.420	0.243	4.941	5.898	
	Red Bull	Baseline	2.573	0.143	2.291	2.855	0.051
		After application	1.990	0.243	1.511	2.468	
EsCom100	Distilled Water	Baseline	1.797	0.143	1.515	2.079	0.0001
		After application	2.184	0.243	1.705	2.662	
	Barbican	Baseline	1.420	0.143	1.138	1.702	0.005
		After application	0.883	0.243	0.404	1.361	
	Bison	Baseline	1.316	0.143	1.034	1.598	0.444
		After application	1.227	0.243	0.749	1.705	
	Red Bull	Baseline	2.170	0.143	1.888	2.452	0.022
		After application	1.669	0.243	1.191	2.147	
Medifil Silver	Distilled Water	Baseline	0.921	0.143	0.639	1.203	0.0001
		After application	2.106	0.243	1.628	2.584	
	Barbican	Baseline	1.527	0.143	1.245	1.809	0.026
		After application	2.567	0.243	2.089	3.046	
	Bison	Baseline	1.400	0.143	1.117	1.682	0.0001
		After application	3.305	0.243	2.827	3.783	
	Red Bull	Baseline	1.518	0.143	1.236	1.800	0.0001
		After application	3.458	0.243	2.979	3.936	

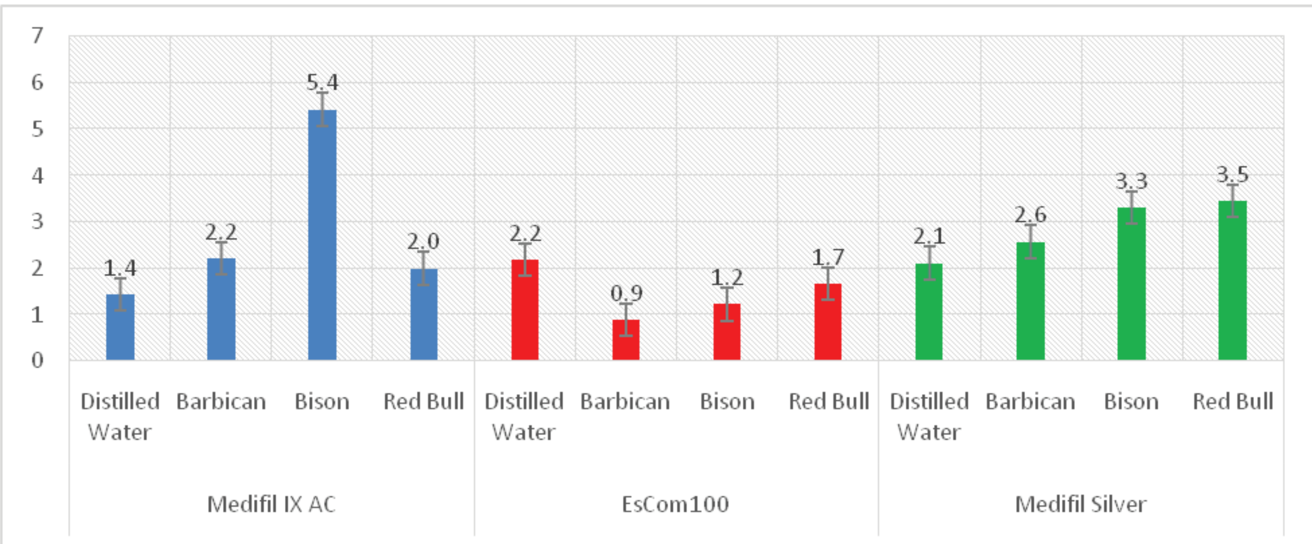

Figure 1: Average color change values (ΔE*) for each restorative material after application of energy drinks and distilled water.

hygiene, and the surface smoothness of the restoration [22]. Even the distilled water resulted in a color change. Previous studies have shown that the water component of the mouthwashes might affect the color stability of restorative materials [23,24]. Furthermore, some researchers observed that water sorption was closely related to stain sorption [25,26]. Therefore, hydrophobic materials such as resin composite were more stain-resistant than hydrophilic materials [25,26]. Previous studies observed that the resin matrix plays a critical role in staining susceptibility [13,15,19].

The staining of restorations is known to be affected by dietary factors [10,27]. Consumption of soft drinks is known to have increased in recent years and is especially high among young individuals [1,2]. Many studies have evaluated the effects of different types of drinks on the stability of color of restorative materials, however, few reports were published on the effect of energy drinks [10,27,28]. Different *in vitro* studies have demonstrated that common food and drinks, such as coffee, cola, tea, fruit juices, soy sauce, mustard, and ketchup could cause a significant change in surface color of resin composite materials and glass ionomers [29,30]. It has been reported that the color difference values (ΔE*) ranging from 1 to 3 are perceptible to the naked eye and ΔE* values greater than three are clinically unacceptable [31]. The present study found the resin composite (EsCom100) to be the most resistant to staining, followed by Silver Medifil, and MedifilIX AC. This result is not in agreement with previous studies, which found that conventional glass ionomer cement has greater color stability than reinforced glass ionomers or resin composites [15,29]. Furthermore, in the present study, all groups showed color changes after the application of energy drinks and distilled water with a statistically significant difference among the restorative materials and energy drinks. In addition, multiple comparison tests showed correlations between different energy drinks and distilled water by the restorative materials at baseline and after application of energy drinks and distilled water. Color changes for tested restorative materials following immersion in energy drinks showed different degrees of visual perceptions, which were considered clinically unacceptable. Color changes for tested restorative materials may be explained by the composition of the energy drinks such as the acidity of 3.3 (Red Bull, barbican) and 3 (Bison) and their effect on the structure of the tested restorative materials. Previous studies have demonstrated that the low pH of active preventive mouthwashes such as fluoride may influence hardness, wear, and color stability [32-34]. The acidity may change the polymeric matrixes of resin composites affecting di-methacrylate monomers, present in their compositions [35,36]. The previous studies suggested that, by lowering the solution's pH level, there is a production of methacrylic acid that results in sorption and hygroscopic expansion as a consequence of enzymatic hydrolysis and biodegradation [35,36]. In addition, the difference in color stability of the tested restorative materials could be due to their different composition. The physical properties of resin composites (EsCom100), the silver reinforced glass ionomer (Silver Medifil), and the glass-ionomers (MedifilIX AC) are dependent on the nature of the resin matrix, filler particle and resin-filler interface [8]. The present study found the resin composite (EsCom100) to be the most resistant to staining, followed by Silver Medifil, and MedifilIX AC. The three restorative materials differ in their composition. EsCom100 is a light-cured nano-hybrid resin composite designed for posterior and anterior restorations, easy polishability, exceptional wear resistance, low polymerization shrinkage, and superior compressive strength, and radiopaque [37]. The latter material showed the highest discoloration after distilled water. Medifil Silver is silver reinforced glass ionomer cement with self-adhesion to tooth substance, increased abrasion resistance, high biocompatibility, and excellent compressive and tensile strength [38]. The latter material showed the highest discoloration after the application of Red Bull. Medifil IX AC is a glass ionomer with excellent packable consistency, strong adhesion to dentin and enamel, high compressive and flexural strength, tooth-like thermal expansion and superior abrasion resistance, highly translucent and radiopaque [38]. The latter material showed the highest discoloration after the application of Bison. In addition, ΔE* decreased after the application of Red Bull for Medifil IX AC and after the application of Barbican, Bison, and Red Bull on EsCom100. This indicates that the color change varied depending on the restorative materials and energy drinks used. However, for all materials, exposure to energy drinks resulted in significantly high rates of color change than exposure to distilled water. In addition, the resin composite showed the most resistance to staining and Medifil IX AC GI showed the least resistance.

A study that evaluated whether energy drinks have an erosive effect on glass ionomer and resin composite restorative materials concluded that all tested energy beverages had an adverse effect on the surface roughness degradation of the tested glass ionomers with increasing immersion time [39,40]. In the present study, all specimens were uniformly prepared to a thickness of 2 mm as measurements of reflective surfaces are affected by the thickness and smoothness of the specimen surface [16,17]. Furthermore, the specimens were immersed in the energy drinks or distilled water for 96 hours as a low period of immersions like three days was reported to be sufficient to evaluate color changes in the resin composites [39].

This study had certain limitations, including its *in vitro* setting. *In vitro* studies like this one can fail to reproduce the oral environment, where saliva, oral mastication, antagonist occlusion, and other factors are present that affect the surfaces of restorative materials. In addition, the clinical condition in the mouth is not easy to mimic in the laboratory setting [40]. Thermocycling was not performed in this study to simulate some aspects of the oral environment. Thermocycling should be included in future studies. Another limitation was the use of only three restorative materials. It would have been valuable if more and different restorative materials/systems had been tested. It would also be beneficial if the application of energy drinks on the tested restorative materials for a longer period was evaluated. Furthermore, the restorative material surfaces were flat, which does not simulate a clinical situation. However, in spite of these limitations, the research designates a number of positive links between an *in vitro* effect and a clinical effect.

Conclusions

Based on this study's results, the following conclusions can be made:

1. The color difference ΔE* between final and initial values after exposure to different staining of energy drinks was unacceptable for all restorative materials tested with the exception of the resin composite.

2. For all materials, exposure to energy drinks resulted in significantly high rates of color change than exposure to distilled water.

3. The resin composite showed the most resistance to staining and Medifil IX AC GI showed the least resistance.

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