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The Effects of Popular Energy Drinks on Surface Hardness of Glass Ionomer Restorations

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Background:

Dental Erosion is defined as the irreversible loss of dental hard tissues by a chemical process without the involvement of microorganisms (1). It is due to either extrinsic or intrinsic acid sources. Extrinsic acids are derived from the environment, medications, lifestyle and diet (2). The overconsumption of dietary acids in the form of soft drinks has been linked to tooth surface loss (3). Exposure to extrinsic acids may also adversely affect dental restorations. This clinically jeopardizes the life of the restoration, as the ultimate success of the restorative material is indicated by its longevity in the oral cavity.

Energy drinks have become an annual 21-billion-dollar industry in the USA (4). The Food and Drug Administration defines energy drinks as a class of products in liquid form that typically contains caffeine, with or without other added ingredients (5). The most popular and studied energy drink is Red Bull, which was first introduced in Austria in 1987 and in the United States in 1997. As a result of aggressive marketing that promoted increased attention, stamina and athletic performance, energy drink manufacturers enjoyed tremendous growth during the mid-2000s. In the year 2007 alone, more than 200 new energy drinks were launched in the United States. Teens and young adults, particularly young men, are identified as the target advertising demographic group for these energy drinks (6). This makes the military population especially prone to energy drink use. Over the last two decades, energy drinks have become increasingly popular among service members because they are thought to enhance performance and alertness. The popularity of these drinks has been strengthened in the military by their widespread availability during deployments where sleep deprivation is common. In 2010, data collected by the Joint Mental Health Advisory Team 7 during Operation Enduring Freedom in Afghanistan showed that 44.8% of deployed service members consumed at least one energy drink daily, with 13.9% drinking three or more daily (7). The most common reasons given for energy drink consumption were to improve mental alertness (61%), mental endurance (29%) and physical endurance (20%) (8). There presently exist hundreds of uniquely branded energy drinks in the United States. Popular brands such as Red Bull, Monster, and Bang enjoy a combined 64% of U.S. energy drink market share and have a strong presence on U.S. military facilities worldwide.

Glass ionomer restorations are used in various applications in dentistry today, including treatment of carious and non-carious cervical defects (erosion, abfractions, abrasion), and as direct restorative materials, sealants, interim restorations and liners or bases. Glass ionomers and resin-modified glass ionomers are unique among dental materials because they release fluoride. They also physically and chemically bond to tooth structure with no need for etch and prime. There are many advantages associated with Glass Ionomer Cements that make them an attractive dental material for use including coefficient of thermal expansion similar to dentin, a modulus of elasticity similar to tooth structure, low polymerization shrinkage, a predictable marginal seal and antibacterial properties. There are also well-known disadvantages to GICs including brittleness, poor wear resistance and poor surface properties including sensitivity to moisture. Studies have shown that no matter what size the filler is present in the resin-modified GICs, their surface roughness and hardness remain significantly lower compared to resin composites. In addition, GICs are more prone to mechanical and chemical degradation and higher solubility than resin composites. Studies have shown that an acidic environment can alter roughness, hardness, fluorescence, intensity, and restorative and prosthodontic frameworks (9). Moreover, fermentable sugars in energy drinks may increase dental biofilm accumulation on tooth surfaces and restorations resulting in dental caries and failed restorations.

Objective

Based on the high prevalence of energy drink consumption among U.S. soldiers and the frequent utilization of glass ionomer and resin-modified glass ionomer restorations in military dental clinics, it is essential to gain a comprehensive understanding of the impact these energy drinks have on such restorations and their performance within the oral environment. The primary aim of this research topic was to investigate the potential effects of commonly consumed energy drinks on the surface hardness of frequently used Glass Ionomer Restorative materials. It is hypothesized that the surface hardness of the tested Glass Ionomer Cements will remain unaltered by the exposure to Monster energy drink and the duration of the exposure will have no effect on the material hardness.

Methods and Materials

This study used sixteen GC FUJI II LC restorations, sixteen GC FUJI IX GP restorations, sixteen EQUIA Forte restorations, and sixteen Filtek Supreme Ultra Flow restorations to evaluate the effect of energy drinks combined with simulated salivary extract (Monster Energy Drink and Hanks Balanced Salt Solution) on the surface hardness of the different Glass Ionomer Restorations. The names of the materials, compositions and manufacturers of the supplies used are listed in Table 1.

Table 1: Materials

Material	Type	Manufacturer	Location
Bulk Fill, Glass Hybrid	Equia Forte	GC America	Alsip, IL
Packable Glass Ionomer	FUJI IX	GC America	Alsip, IL
Resin Modified Glass Ionomer	Fuji II LC	GC America	Alsip, IL
Monster Energy Drink	Original	Monster Beverage	Corona, California
Surface Hardness	LM300AT	LECO Corporation	St. Joseph, MI
Dykstra EMS Embedding Mold	Stepped Microtome Catalog # 70907	Electron Microscopy Sciences	Hatfield, PA
Curing Light	Mini L.E.D. (Light Emitting Diode) #303677-019	Acteon Satelec	California U.S.A.
Simulated Salivary extract	Hanks Balanced Salt Solution, 1X	Corning Cellgro	Manassas, VA
Matrix Strips	DuPont Mylar 10cmx0.95cm MFG#20 95-8205	Patterson Dental Supply	Montreal, Quebec
Laboratory Incubator	Heratherm Oven Mo # 3700-87	Thermo Scientific	Anaheim, CA

Specimen preparation

Each restorative material (FUJI II LC, FUJI IX GP, EQUIA FORTE, and flowable composite) was prepared as sixteen cubic specimens each, using a 4 mm x 3mm Heliotest Teflon mold (Electron Microscopy Science, Catalog # 70907, Hatfield, PA). The prepared materials slightly overfilled the molds. Careful preparation of the Glass Ionomer and flowable composite occurred with proper isolation and the use of a mylar strip (DuPont Mylar, MFG #20 95-8205, Montreal, Quebec) to help remove voids and excess material. A LED light cure unit (Mini L.E.D. (Light Emitting Diode) #303677-019, California U.S.A.) with a light intensity of 665m W/Cm cured and polymerized the RMGI and composite restorations according to the manufacturer's instructions.

After preparation, the polishing of all restorations occurred with their respective restorative polishing points and burs. All specimens were then soaked in normal saline at 37 degrees Celsius for 24h. Preparations were blotted dry and initial measurements taken with the LM300AT microhardness tester to determine baseline microharness.

Specimens were stored in 97.8 degree Fahrenheit heratherm laboratory incubator for the duration of the experiment to represent the average temperature of the human mouth. Each restorative specimen group was subdivided into two groups (Group A – 8 samples and Group B – 8 samples). Group A was soaked in 20mL of Monster Energy drink and 10ml of the salivary substitute liquid for 8 hours each day. Group B was soaked in the salivary substitute liquid alone for 24 hours each day. The examiner measured the microhardness after 24 hours, 72 hours, 120 hours, and 168 hours. The need to evaluate the surface degradation at shorter time intervals occurred due to the limited time constraints. The LM300AT microhardness tester was used to evaluate and quantify the surface microhardness of the restorations.

All specimens were subjected to surface microhardness testing (KHN). Each specimen's surface was indented at three points using a 200g load at a dwell time of 15 seconds. The average of these three indentations was then calculated.

Statistical Analysis

A two-factor repeated measure analysis of variance (ANOVA) was used to assess the effect of time and time-group interaction. Results are reported using the Greenhouse-Geisser correction due to violations of the assumption of sphericity in the data. The Shapiro-Wilk test was used to verify assumptions of normality. Independent t-test were used to compare changes from baseline. Continuous data are reported as means with associated standard deviations. For all tests, significance was declared at $P < 0.05$. All analysis were accomplished using SPSS v25.

Results:

A total of 64 microhardness readings were taken from samples at five time points. Table 1 reports baseline and follow-up data by restorative material. Overall, no difference was noted between samples exposed to energy drink versus salt solution at baseline, 24hrs, 48hrs, and 120hrs, all $P > 0.05$. Only after 168 hours was a significant main effect found based on exposure, $P = 0.04$. As expected, the samples soaked in energy drink had a lower mean hardness (KHN = 40.4, SD = 26.3) compared to salt solution (KHN = 54.6, SD = 26.6). See Figure 1.

Significant main effects of restorative material type were found at each time point and under both the energy drink and salt solution conditions (all $P<0.001$). Additionally, an interaction effect was observed between time and restorative material, $P<0.001$. At baseline, among the energy drink exposed samples, Equia Forte were found to have the highest mean hardness (KHN = 76.0, SD = 4.5) whereas samples made with Filtek Supreme Ultra Flow had the lowest (KHN = 29.3, SD = 5.3). After 168 hours of energy drink exposure, Equia Forte maintained its mean hardness (KHN = 75.0, SD = 3.4, $P = 0.26$). In contrast, samples of Fuji II fell 84.1% from a KHN of 42.1 (SD = 7.4) to 6.7 (SD = 1.0), $P = 0.01$.

Even under the salt solution condition, samples of Fuji II were found to have suffered a significant reduction in hardness (-24.4%) from baseline to 168 hours, $P=0.02$. Interestingly, samples of Fuji IX were found to have significantly increased in hardness during the 168 hours of exposure from a baseline KHN of 69.4 (SD = 3.4) to 75.6 (SD = 3.0), $P = 0.01$. Changes from baseline are shown in Table 2.

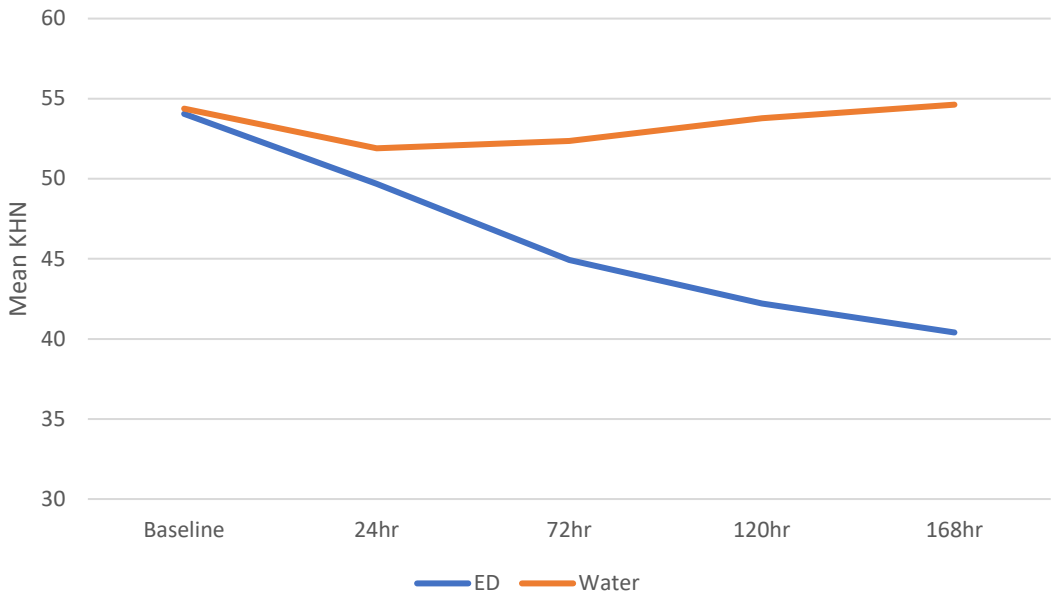
Table 1. *Mean Microhardness (KHN) by Material and Time, M (SD)*

Exposure	Material	Baseline	24hr	72hr	120hr	168hr	P[1]
Energy Drink	Fuji II	42.1 (7.4)	28.9 (4.2)	16.2 (2.6)	10.5 (1.8)	6.7 (1.0)	0.01
	Fuji IX	68.7 (5.1)	66.3 (6.6)	59.6 (9.2)	55.4 (6.9)	52.4 (4.3)	0.01
	Equia Forte	76.0 (4.5)	75.6 (5.1)	75.3 (3.8)	74.1 (4.8)	75.0 (3.4)	0.26
Saliva Substitute	Fuji II	32.8 (7.4)	30.1 (3.6)	28.8 (3.6)	28.4 (3.0)	24.8 (2.1)	0.02
	Fuji IX	69.4 (3.4)	70.9 (5.3)	70.0 (4.3)	74.8 (4.7)	75.6 (3.0)	0.01
	Equia Forte	81.3 (4.1)	72.9 (4.9)	76.0 (4.5)	78.9 (4.5)	85.0 (4.1)	0.16

Table 2. Microhardness Percent Change from Baseline

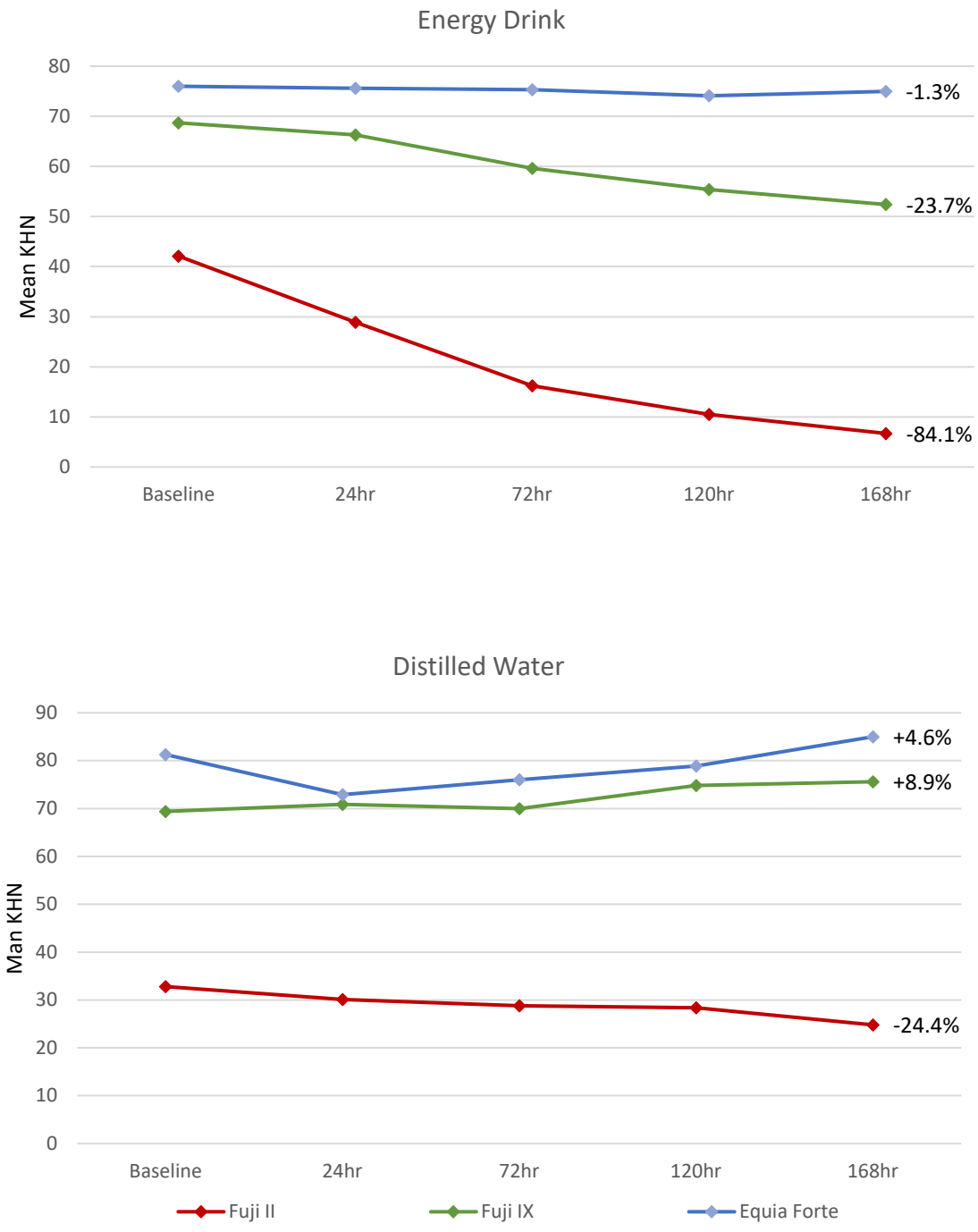
Exposure	Material	Baseline	24hr	72hr	120hr	168hr
Energy Drink	Fuji II	0.0%	-31.4%	-61.5%	-75.1%	-84.1%
	Fuji IX	0.0%	-3.5%	-13.2%	-19.4%	-23.7%
	Equia Forte	0.0%	-0.5%	-0.9%	-2.5%	-1.3%
Saliva Substitute	Fuji II	0.0%	-8.2%	-12.2%	-13.4%	-24.4%
	Fuji IX	0.0%	+2.2%	+0.9%	+7.8%	+8.9%
	Equia Forte	0.0%	-10.3%	-6.5%	-3.0%	+4.6%

Figure 1.



Mean Microhardness Over Time by Exposure

Figure 2. Hardness Over Time by Exposure and GIC Type



Discussion

Studies have shown that there has been an increase in Energy drink usage in the military, especially among deployed soldiers. The three most common reasons for this increased usage are attributed to their ability to increase mental alertness (61%), mental endurance (29%) and physical endurance (20%). The main ingredients of energy drinks are caffeine, taurine, glucoronolactate, B vitamins, guarana, ginseng, ginko biloba, L-carnitine, sugars, antioxidants, and trace minerals. These energy drinks have already been shown to have a negative effect on enamel and dentin due to the low pH associated with these drinks. The majority of energy drinks have a pH below 4.0 (10). The critical pH of enamel is 5.5, and the critical pH of dentin is 6.5. The frequent consumption of these energy drinks have been proven to play a role in dental erosion, which is defined as a non-bacterial chemical process that leads to the softening and cumulative loss of hard dental tissues (11). Often these areas where erosion occurs in enamel or dentin, restorations are placed. Therefore, it is important to understand how these energy drinks not only effect natural tooth structure but also effect the these restorations.

Glass Ionomer cement is a self-adhesive restorative material that exhibits potent anticariogenic action. Chemically, it is a combination of fluoro-aluminosilicate glass powder, polyacrylic acid, tartaric acid and water. It is a versatile material and has a broad spectrum of uses in restorative and pediatric dentistry. The three GICs chosen for this study exhibited varying results in hardness when exposed to Monster Energy Drink. These differences in hardness are likely attributed to differences in content.

FUJI II LC is considered a light cure resin reinforced GIC that sets through a combination of auto-cure acid base reaction and light initiated polymerization of the resin component. FUJI II's indications for use include cervical erosions, class V, bases/liners and non-load bearing class II restorations. FUJI II's performance to hardness testing both when soaked in Monster energy drink and saliva substitute were markedly decreased when compared to the other GIC's tested. This may contribute to the reason that these restorations are not indicated in stress bearing areas

FUJI IX is considered a packable GIC setting through an auto-cure acid base reaction. It is used as an amalgam/composite/compomer alternative and is indicated to be placed in Class I and Class II restorations. Although there was a decrease in hardness when soaked in Monster Energy Drink, the hardness of this material outperformed FUJI II under both conditions

Equia Forte is considered a bulk fill, fluoride releasing, glass hybrid. It is indicated in class I and class II stress bearing areas and is advertised to have superior strength, wear resistance and fluoride release. Equia Forte maintained its hardness the best out of any other GIC tested in both the Monster immersion group and the Salivary substitute immersion group.

Hardness is an important surface property for a restorative material. Hardness can be a suitable estimate of the clinical life of a restoration (12). Hardness also correlates well with compressive strength and intra-oral softening. A low surface hardness value is largely related to inadequate wear resistance and proclivity to scratching, which can compromise fatigue strength and lead to failure of restorations. It is prudent to evaluate hardness of a restorative material.

Conclusions

It has been established that acidic environments can lead to erosion of natural tooth structure. Energy drinks contribute to this potential acidic environment. This study has demonstrated that energy drinks may also have a negative effect on restorations that are placed in the mouth as well, namely GIC restorations. All of the GICs tested in this study exhibited decreased hardness at 168hrs when compared to baseline hardness when soaked in Monster Energy Drink. FUJI II appeared to be more effected by immersion in Monster energy drink, as this material demonstrated the largest decrease in hardness as compared to baseline. Equia Forte's hardness at 168h was the closest to its baseline hardness out of all GIC restorations studied, indicating that this material's hardness was the least effected by the immersion in Monster Energy Drink. These results indicate that Equia Forte may be the GIC of choice when considering restorations in individuals with high energy drink consumption. More research should be conducted into how energy drinks effect restorative materials, so that clinicians can more accurately select restorations that will provide the most benefit and long-term success to the patient.

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Disclaimer

The views expressed herein are those of the author(s) and do not necessarily reflect the official policy of the Department of the Army, Defense Health Agency, Department of Defense, or the US Government.

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