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Influence of Sport Beverages on the Properties of Dental Restorative Glass Ionomers

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Abstract

Background and objectives: Energy drinks have an erosive effect and risks to clinical performance of glassionomer restorative materials. This study was conducted to evaluate the influence of sport and energy drinks on conventional and resin-modified glass ionomer restorative materials regarding fracture toughness, surface roughness and fluoride release.

Methods: The restorative materials used were conventional and resin-modified glass ionomer. Sport drinks were Gatorade Perform 02 and Pocari sweat, while the energy drinks were Red Bull and Power Horse. Specimens prepared and divided into five groups according to the testing medium (distilled water, two sport drinks and two energy drinks) for 1 and 7 days. The fracture toughness was determined using three-point bending method. Surface roughness was measured using surface profilometer. Fluoride release was determined using a conventional ion chromatograph testing unit. The data were analyzed using three-way ANOVA and Least Significant Difference test. For comparison between the two materials under each condition, t-test was used.

Results: There was no significant difference in fracture toughness between sport and energy drinks and distilled water at different time intervals except for conventional glass ionomer after 7 days. Resin-modified glass-ionomer exhibited smoother surfaces more than conventional one in sport and energy drinks after 1 day. After 7 days, both conventional and resin-modified glass ionomers showed greater surface roughness. Both conventional and resin-modified glass ionomers release more fluoride in acidic beverages than distilled water.

Conclusion: The effect of sport and energy drinks on the fracture toughness may depend on the composition and acidity of drink. Fluoride release increased with the consumption of sport and energy drinks.

Keywords: Sport beverage; Energy beverage; Glass ionomer; Restorative materials

Introduction

Fluid replacement drinks or carbohydrate-electrolyte beverages may be one of the most researched sports nutrition topics ever and accompanying this high volume of research are continually evolving recommendation [1]. Sport drinks were developed in the United States in 1960s when the University of Florida Gators began drinking a formulation of carbohydrate and electrolytes to enhance their performance and prevent dehydration. Most marketing for these beverages is now aimed at the nonathletic [2].

Sport drinks are popular worldwide, but the various products differ little in their composition. They contain 6% to 8% carbohydrates, with the principal carbohydrates being glucose, fructose, sucrose, and synthetic maltodextrins. All contain small amounts of electrolytes, including sodium, potassium and chloride, to improve palatability and help maintain the fluid/electrolyte balance. The purpose of sport drinks is to prevent dehydration, to provide carbohydrates to boost energy, to supply electrolytes that can replace those lost via perspiration [3].

In 2006, nearly 500 new brands of energy drinks were introduced and more than 7 million adolescents reported that they have consumed an energy drink. The difference between sport and energy drinks that sport drinks tend to be caffeine free, but energy drinks are loaded with caffeine. Energy drinks also tend to have a higher carbohydrate content (9% to 10%) than do sport drinks [2].The dental status of athletes who consume these acidic beverages is little considered. These beverages have an erosive effect and risks to dental health [4].Clinical performance of filling materials is affected by erosion as well [5].

Glass ionomer restorative materials have a number of unique properties, including adhesion to tooth structure, biological compatibility, and anticariogenic properties due to their fluoride release [6].The ability of restorative dental materials to withstand the functional force and exposure to various media in the mouth is an important requirement for their clinical performance for considerable period of time. However, although these materials are tested for strength, they are rarely tested following storage in a kind of aqueous media found in the mouth. Instead, they are tested after being stored in deionized water of high purity [7]. For ionic restorative materials, such as glass ionomer, this storage regime may be inappropriate. These restorative materials have recently been shown to interact with various aqueous media. For example; in saliva, they undergone a surface reaction that led to precipitation of calcium and phosphate ions into the outermost layer [7,8]. In acidic conditions, matrix forming ions were found to be released into solution as part of a process of buffering the medium [9]. There was a significant reduction in surface hardness of the restorative materials over a 6-month immersion period in sport and energy drinks [10].

It was found that glass ionomer in orange and apple juice underwent severe erosion and loss of strength. This was attributed to the presence of carboxylic acids such as citric and malic acids in these fruit juices, which are capable of chelating with cement-forming ions, such as calcium, to yield soluble products [7].Therefore, for these materials, the nature of the storage medium is important. So, the null hypothesis of this study was sport and energy drinks will negatively affect the properties of glass ionomer restorative materials.

Materials and Methods

The materials used in this study are listed in Table 1. A conventional glass ionomer (Iono gem), a resin-modified glass ionomer (Iono gem LC), two types of sport drinks (Gatorade Perform 02 and Pocari Sweat), and two types of energy drinks (Red Bull and Power Horse) were used. The pH of each beverage was determined using a calibrated pH meter (HANNA instruments, HI 98150 Microprocessor Logging pH/ORP Meter, Romania) that was placed directly into each solution. The pH meter which has an accuracy of 0.1, was first calibrated according to manufacturer's instructions, employing buffer standards of pH 7 and pH 4. The measurements were taken at a room temperature. Fifty mL of each beverage was placed in a beaker, the pH meter was inserted and the reading was recorded [11].

Three tests were performed; fracture toughness, surface roughness and fluoride release. Specimens prepared for each material were manipulated according to manufacturer's instructions.

They were divided into five groups according to the storage medium

Group 1: Specimens were immersed in distilled water (control).

Group 2: Specimens were immersed in Gatorade Perform 02.

Group 3: Specimens were immersed in Pocari Sweat.

Group 4: Specimens were immersed in Red Bull.

Group 5: Specimens were immersed in Power Horse.

Materials	Type and Composition	Manufacturers
Ionogem	Conventional glass ionomer restorative Dental Composite material (hand mixed)	England
Ionogem	Resin-modified glass ionomer restorative Dental Composite	England
Gatorade Perform 02	Sport drink, Water, sucrose, dextrose, citric acid, natural flavor,salt, sodium citrate Monopotassium phosphate, gum arabic, yellow 6, glycerol ester of rosin, brominated vegetable oil	Gatorade, USA
Pocari Sweat	Sport drink, Water, sugar, Citrus flavor, citric acid, sodium citrate, sodium chloride, potassium chloride, malic acid, calcium lactate, glucono delta-lactone. Monosodium L-glutamate, magnesium carbonate, vitamin C	P.T Amerta, Indah Otsuka, Jakarta, Indonsia
Red Bull	Energy drink, Water, sucrose, gluose, sodium citrate, carbon dioxide, taurine0.4%, glucoronolactone 0.24%, caffeine 0.03%, niacin, B-group vitamins, flavors	Red Bull, GmbH, Austria
Power Horse	Energy drink, Carbonated water, sucrose, glucose, citric acid, taurine, glucuronolactone, artificial flavor, caffeine, inositol, niacin, pantothenic acid, vit B6, B12, riboflavin	S.Spitz GmbH, Austria

Table 1: Materials used

The pH of each storage medium was determined before immersion of the specimens.

Determination of fracture toughness

A total number of hundred and forty notched specimens were prepared, seventy specimens for each glass ionomer. Specimens were prepared in a stainless-steel split mould (25 mm length × 2.5 mm thickness × 5 mm width). The mold was notched (0.5 mm width and 2.5 mm depth) [12]. The mixed cement was condensed into the mold, pressed between matrix strips and glass plates under load for 10 min. The light-cured glass ionomer, the specimens were light-cured at each surface using an overlapped technique for 40 s using a visible light curing unit at 320 mW/cm^2 (Visilux II; 3M, St Paul, USA). After approximately one hour in a humidor, each specimen was removed from its mold [12,13]. The specimens were divided as mentioned before (n = 7/group for each test period).

The specimens were immersed in 5 mL of the testing medium and stored at 37oC. Specimens were tested after 24 h and after one week from the start of immersion. The storage medium was changed daily. Fracture toughness was determined using three-point bending method according to the procedures outlined in ASTM E399-90 [14].The test was done using a computer-controlled Universal Testing Machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5 kN and data were recorded using computer software (Nexygen-MT; Lloyd Instruments). The specimens were loaded until fracture at a crosshead speed of 0.5 mm/min. Fracture toughness, K_{Ic}(MPa. m 1/2), was calculated from the following equation [14]:

$$K_{Ic} = (P_Q S/BW^{3/2}).f\,(a/W)$$

Where: P_Q is the peak load (kN), B is the specimen thickness (cm), S is the span length (cm), W is the specimen width (cm), a is the crack length (cm) and f (a/W) is a function of a/W.

Determination of surface roughness

A total number of fifty disc-shaped specimens, twenty five for each restorative material, were fabricated in a split Teflon mould (10 mm diameter × 2 mm) thickness. The cement paste was packed into the mold that was placed on a microscope slide. A second slide was placed over the mold and light hand pressure applied to enable the excess material to flow out of the mold through the slit. Resin-modified glass ionomer specimens were light cured at each surface of the specimens. The specimens were divided into five equal groups (n = 5/group) according to the storage medium as mentioned before.

The specimens were immersed in 5 mL of the testing medium and stored at 37°C. Surface roughness was measured after 24 h and one week from the start of immersion. The storage medium was changed daily. Surface roughness was measured using surface Profilometer (Surf Test SJ 201, Japan). Five tracings at different locations on each specimen were made. Surface roughness (Ra) was determined in µm using a tracing length of 2 mm and a cutoff value of 0.25 mm to maximize filtration of surface waviness.

Measurement of fluoride release

A total number of fifty disc-shaped specimens, twenty five specimens for each glass ionomer, were divided into five equal groups (n = 5/group), according to the storage medium as mentioned before. The specimens were fabricated in the split Teflon mold that was used for preparing specimens for surface roughness testing. The specimens were immersed in 5 mL of the storage medium and stored at 37°C. The measurement of fluoride release from the specimens was carried out at the following time intervals: 24 h, 3 days, 5 days and 7 days from the start of immersion. At each test interval, the specimen was removed from the solution, quickly blotted dry with filter paper and immediately immersed in another 5 mL of the storage medium. An Ion Chromatograph (DX 500; Dionex, Camberley, UK) with suppressed conductivity was used for free fluoride ion determination.

The instrument was fitted with an ION PAC AS14 analytical column (Dionex) and ION PAC AG14 Guard column (Dionex). A half mL of each storage solution was injected onto the injection loop of the instrument. The loop was designed such that 250 µL was fed to the column for analysis. A flow rate of 1.2 mL/min was used. Free fluoride ions have a well-defined retention time and the peak corresponding to fluoride could readily be determined from the chromatogram. The peak area was used to determine fluoride concentrations by linear interpolation between standard solutions of concentration slightly higher and lower than the test solution. The determination of each solution was made three times and fluoride concentration determined to an accuracy of 0.001 ppm [15].

Statistical analysis

Means and standard deviations of fracture toughness, surface roughness and fluoride release were calculated for each group. The data were analyzed using three-way ANOVA and Least Significant Difference (LSD) tests. For comparison between the two materials under each condition, unpaired student's t-test was used. The statistical analysis was performed by Statistical Package for Social Science (SPSS) version 15. All statistical analysis were performed at $\alpha=0.05$.

Results

pH of immersion media

The measured pH of different immersion media were as follow: pH of distilled water was 6.3, Gatorade Perform 02 was 2.9, Pocari Sweat was 3.3, Red Bull was 3.1and Power Horse was 2.8.

Fracture toughness

Mean values and standard deviations of fracture toughness of the studied materials after immersion in different media for 1 and 7 days are shown in Tables 2 and 3. After 1 day, for conventional glass ionomer, the lowest mean fracture toughness value was for specimens immersed in Gatorade, and the highest means were for specimens immersed in distilled water and Pocari Sweat. For resin-modified glass ionomer, the lowest mean fracture toughness value was for specimens immersed in Pocari Sweat and the highest mean was for specimens immersed in Power Horse.

After 7 days, for conventional glass ionomer, the lowest mean fracture toughness value was for specimens immersed in Power Horse and the highest means were for specimens immersed in distilled water. For resin-modified glass ionomer, the lowest mean fracture toughness value was for specimens immersed in Red Bull and the highest mean was for specimens immersed in Pocari Sweat. Three-way ANOVA results of fracture toughness are presented in Table 4. There was a significant effect of material, storage media and immersion time ($P<0.05$). In addition there was a significant interaction between material, storage media and immersion time and with each other ($P<0.05$). LSD test (Table 2) showed that there was no significant difference between different storage media after 1 day for both studied materials. In addition, after 7 days (Table 3), there was no significant difference between different media for both studied materials except for conventional glass ionomer specimens immersed in Red Bull and Power Horse. Results of t-test (Tables 2 and 3) showed that resin-modified glass ionomer exhibited significantly higher fracture toughness than conventional glass ionomer either after 1 day or 7 day of .immersion. In addition, there was no significant difference between 1 day and 7 days of immersion (Table 5) for both materials except conventional glass ionomer specimens immersed in Red Bull and Power Horse.

Surface roughnes

Mean values and standard deviations of surface roughness of the studied materials after immersion in different media for 1 and 7 days are shown in Tables 6 and 7. After 1 day, for conventional glass ionomer, the smoothest surfaces were for specimens immersed in distilled water, and the roughest surfaces were for specimens immersed in Power Horse. For resin-modified glass ionomer, the smoothest surfaces were for specimens immersed in distilled water, and the roughest surfaces were for specimens immersed in Power Horse.

After 7 days, for conventional glass ionomer, the smoothest surfaces were for specimens immersed in distilled water and the roughest surfaces were for specimens immersed in Red Bull. For resin-modified glass ionomer, the smoothest surfaces were for specimens immersed in distilled water and the roughest surfaces were for specimens immersed

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	0.62 ± 0.1[a]	0.54 ± 0.1[a]	0.62 ± 0.1[a]	0.6 ± 0.1 [a]	0.6 ± 0.1[a]
IonoGem LC	2.33 ± 0.1[a]	2.36 ± 0.2[a]	2.3 ± 0.1 [a]	2.4 ± 0.2 [a]	2.5 ± 0.2 [a]
T-value	-26.45	-28.57	-29.4	-20.09	-14.46
P-value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 2: Means, standard deviations, results of LSD and t-tests of fracture toughness (MPa.m$^{1/2}$) of the studied materials in different media after 1 day.
Means with same superscript letters in each row are not significantly different (LSD test).
*Significant at P<0.05

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	0.63 ± 0.1[a]	0.53 ± 0.1[a]	0.63 ± 0.1[a]	0.25 ± 0.1[b]	0.24 ± 0.1 [b]
IonoGem LC	2.39 ±0.1[a]	2.39 ± 0.1[a]	2.42 ± 0.1[a]	2.31 ± 0.1[a]	2.33 ± 0.2[a]
T-value	-28.3	-33.88	-42.9	-45.24	-29.01
P-value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 3: Means, standard deviations, results of LSD and t-tests of fracture toughness (MPa.m$^{1/2}$) of the studied materials in different media after 7 days
Means with same superscript letters in each row are not significantly different(LSD test).
*Significant at P<0.05

Source	Sum of Squares	df	Mean Square	F-value	P-value
Material	115.851	1	115.851	6,882.020	0.000*
Storage media	0.465	4	0.116	6.908	0.000*
Immersion time	0.101	1	0.101	5.999	0.016*
Material *Storage media	0.220	4	0.055	3.273	0.014*
Material * Immersion time	0.262	1	0.262	15.560	0.000*
Storage media * Immersion time	0.464	4	0.116	6.884	0.000*
Material * Storage media * Immersion time	0.205	4	0.051	3.045	0.020*
Error	2.020	120	0.017		
Total	410.776	140			

Table 4: Three-way ANOVA showing the effect of material, storage media, immersion time and the interaction on fracture toughness (MPa. m $^{1/2}$)of the studied materials (P<0.05)

*Statistically significant difference at P<0.05.

		1 day	7 days	P value
IONO GEM	Distilled water	0.62 ± 0.1	0.63 ± 0.1	>0.05
	Gatorade Perform 02	0.54 ± 0.1	0.53 ± 0.1	>0.05
	Pocari Sweat	0.62 ± 0.1	0.63 ± 0.1	>0.05
	Red Bull	0.6 ± 0.1	0.25 ± 0.1	<0.05 *
	Power Horse	0.6 ± 0.1	0.24 ± 0.1	<0.05 *
IONO GEM LC	Distilled water	2.33 ± 0.1	2.39 ± 0.1	>0.05
	Gatorade Perform 02	2.36 ± 0.2	2.39 ± 0.1	>0.05
	Pocari Sweat	2.3 ± 0.1	2.42 ± 0.1	>0.05
	Red Bull	2.4 ± 0.2	2.31 ± 0.1	>0.05
	Power Horse	2.5 ± 0.2	2.33 ± 0.2	>0.05

Table 5: Means, standard deviations and results of t-test of fracture toughness (MPa.m$^{1/2}$) of the studied materials in different media after 1 and 7 days

*Statistically significant difference at P<0.05.

in Power Horse. The three-way ANOVA results of surface roughness are presented in Table 8. There was a significant effect of materials, media and immersion time (P<0.05). In addition there was a significant interaction between material, storage media and immersion time and with each other (P<0.05). LSD test (Table 6) showed that after 1 day, for conventional glass ionomer, there was a significant difference between distilled water and the other storage media. For resin-modified glass ionomer, there was no significant difference between distilled water and the other storage media. After 7 days (Table 7), there was a significant difference between distilled water and the other storage media for both glass ionomers. Results of t-test (Tables 6 and 7) showed that resin-modified glass ionomer exhibited smoother surfaces than conventional glass ionomer either after 1 or 7 days of immersion. In addition, there was a significant difference between 1 day and 7 days of immersion for both studied materials in different storage media except distilled water (Table 9).

Fluoride release

Mean values and standard deviations of fluoride release of the studied materials after 1, 3, 5 and 7 days are shown in Tables 10-13. After 1 day, for conventional glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse. For resin-modified glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse (Table 10). After 3 days, for conventional glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Red Bull. For resin-modified glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse (Table 11). After 5 days, for conventional glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse. For resin-modified glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse (Table 12). After 7 days, for conventional glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse. For resin-modified glass ionomer, the lowest mean fluoride release value was for specimens immersed in distilled water and the highest mean was for specimens immersed in Power Horse (Table 13). The three-way ANOVA results of fluoride release are presented in Table 14. There was a significant effect of material, storage media and immersion time (P<0.05). In addition there was a significant interaction between material, storage media and immersion time and with each other (P <0.05). LSD test (Table 10) showed that after 1 day, there was a significant difference between different storage media for both studied materials. After 3days (Table 11), there was a significant difference between different storage media except Red Bull and Power Horse for both studied materials. After 5 days (Table 12), for conventional glass ionomer, there was a significant difference between different storage media except Red Bull and Power Horse. For resin-modified glass ionomer, there was a significant difference between distilled water and all storage media and between Pocari Sweat and the other storage media. After 7 days (Table 13), for conventional glass ionomer, there was a significant difference between different storage media except Red Bull and Power Horse. For resin-modified glass ionomer, there was a significance difference between distilled water and all storage media and between Pocari Sweat and the other storage media. Results of t-test (Tables 10-13) showed that there were significant differences between conventional and resin-modified glass ionomers at different times. Results of LSD test (Table 15) showed that, for conventional glass ionomer, there was a significant difference of fluoride release among different immersion times for all storage media except Pocari Sweat, there was no significant difference between fifth day and seventh day of immersion. For resin-modified glass ionomer, there was a significant difference among different immersion times for all storage media except distilled water and Pocari Sweat, there was no significant difference between third, fifth and seventh days of immersion.

Product	Distilled water	Gatorade Perfom 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	0.7 ± 0.02b	1.07 ± 0.2a	1.02 ± 0.2a	1.34 ± 0.3a	1.4 ± 0.4a
IonoGem LC	0.52 ± 0.02a	0.68 ± 0.1a	0.692 ± 0.2a	0.84 ± 0.3a	0.87 ± 0.2a
T value	10.7	4.3	2.8	2.77	3.2
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 6: Means, standard deviations, results of LSD and t-tests of surface roughness (Ra, μm) of the studied materials in different media after 1 day
Means with same superscript letters in each row are not significantly different.

Product	Distilled water	Gatorade Perfom 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	0.8 ± 0.1 c	2.08 ± 0.5b	1.94 ± 0.5b	3.8 ± 0.2a	3.7 ± 0.3a
IonoGem LC	0.59 ± 0.05 b	1.02 ± 0.02a	1.1 ± 0.01a	1.82 ±0.5a	1.96 ± 0.1a
T value	5.1	4.7	3.9	8.2	12.04
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 7: Means, standard deviations, results of LSD and t-tests of surface roughness (Ra, μm) of the studied materials in different media after 7 days
Means with same superscript letters in each row are not significantly different.

Source	Sum of Squares	df	Mean Square	F	P
Material	23.368	1	23.368	485.046	0.000*
Storage media	12.419	4	3.105	64.447	0.000*
Immersion time	16.761	1	16.761	347.908	0.000*
Material *Storage media	6.757	4	1.689	35.064	0.000*
Material * immersion time	10.472	1	10.472	217.363	0.000*
Storage media * Immersion time	8.826	4	2.206	45.800	0.000*
Material * Storage media * Immersion time	5.820	4	1.455	30.204	0.000*
Error	3.854	80	0.048		
Total	232.181	100			

Table 8: Three-way ANOVA showing the effect of material, storage media, immersion time and the interaction on surface roughness (Ra, μm) of the studied materials (P < 0.05)
*Statistically significant difference at P < 0.05.

		1 day	7 days	P value
IonoGem	Distilled water	0.7 ± 0.02 b	0.8± 0.1 c	>0.05
	Gatorade Perform 02	1.07 ± 0.2	2.08 ± 0.5	<0.05*
	Pocari Sweat	1.02 ± 0.2	1.94 ± 0.5	<0.05*
	Red Bull	1.34 ± 0.3	3.8 ± 0.2	<0.05*
	Power Horse	1.4 ± 0.4	3.7 ± 0.3	<0.05*
IonoGem LC	Distilled water	0.52 ± 0.02 a	0.59± 0.05 b	>0.05
	Gatorade Perform 02	0.68 ±0.1	1.02 ±0.02	<0.05*
	Pocari Sweat	0.692 ± 0.2	1.1 ±0.01	<0.05*
	Red Bull	0.84 ± 0.3	1.82 ±0.5	<0.05*
	Power Horse	0.87 ± 0.2	1.96 ±0.1	<0.05*

Table 9: Means, standard deviations and results of t-test of surface roughness (Ra, μm) of the studied materials in different media after 1and 7 days
*Statistically significant difference at P < 0.05

Discussion

It is well known that glass-ionomer cements (GICs) are clinically attractive dental restorative materials. These cements possess certain unique properties that make them useful as restorative and adhesive materials, including adhesion to tooth structure and base metals, anticariogenic properties due to release of fluoride, thermal compatibility with tooth enamel because of low coefficients of thermal expansion similar to those of tooth structure, biocompatibility and low cytotoxicity [16]. Sport and energy drinks are popular worldwide. Sport drinks are typically formulated to prevent dehydration, supply carbohydrates to augment available energy, provide electrolytes to replace losses due to perspiration, and be highly palatable [17]. Energy drinks are designed to enhance alertness or provide a short-term energy boost. They derive their energy-boosting properties chiefly from sugar and caffeine [18].

In the oral cavity, restorative materials are exposed to varying environments. These include changes in temperature and acidic-base conditions from food and drinks. Therefore, the restorative materials used in the mouth should resist or show minimal change in these situations. Therefore, a long immersion time was used as an alternative for presenting the extensive effect of acidic beverages on conventional and resin-modified glass ionomer restorative materials [19].

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	80.4 ±1.8[e]	367.2 ± 7.8[c]	296 ±10.5[d]	428.2 ±3.2[b]	438.2 ±3.3[a]
IonoGem LC	16.1 ± 1.96[e]	94.88 ± 1.5 [c]	82.2 ± 3.4[d]	106.74 ± 3[b]	117.6 ± 3.0[a]
T value	53.7	89.89	85.69	30.9	76.7
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 10: Means, standard deviations, results of LSD and t-tests of fluoride release (ppm) of the studied materials in different media after 1 day
Means with same superscript letters in each row are not significantly different.

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	49.6 ±1.0[d]	266.5 ± 6.5[b]	197.8 ±16.0 [c]	283.02 ±. 05.0[a]	281.8 ± 4.5[a]
IonoGem LC	6.3 ± 0.4[d]	70.4 ± 3.2[b]	47.4 ± 1.9 [c]	85.9 ± 4.0[a]	89 ± 3.3[a]
T value	69.4	43.07	52.2	64.76	20.9
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 11: Means, standard deviations, results of LSD and t-tests of fluoride release (ppm) of the studied materials in different media after 3 days
Means with same superscript letters in each row are not significantly different.

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	25.3± 0.9[d]	233.6 ± 5.5[b]	188.2 ± 12.55[c]	259.8 ± 3.8[a]	264 ± 4.8[a]
IonoGem LC	1.76 ± 0.2[c]	59.88 ± 2.4[a]	45.2 ± 4.7[b]	58.9 ± 2̇4a	62.6 ± 3.3[a]
T value	23.8	58.45	162.5	101.1	87.4
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 12: Means, standard deviations, results of LSD and t-tests of fluoride release (ppm) of the studied materials in different media after 5 days
Means with same superscript letters in each row are not significantly different.

Product	Distilled water	Gatorade Perform 02	Pocari Sweat	Red Bull	Power Horse
IonoGem	15.82 ± 1.0[d]	171.8 ± 4.4[c]	186.4 ± 4.5[b]	193.7 ± 4.54[a]	194.52 ± 3.1[a]
IonoGem LC	1.63 ± 0.13[c]	49.12 ± 2.7[a]	41.5 ± 3.22[b]	48.38 ± 3.19[a]	51.94 ± 2.9[a]
T value	58.5	158.5	77.26	76.6	74.9
P value	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*

Table 13: Means, standard deviations, results of LSD and t-tests of fluoride release (ppm) of the studied materials in different media after 7 days
Means with same superscript letters in each raw are not significantly different.

Source	Sum of Squares	df	Mean Square	F	P
material	1,326,191.780	1	1,326,191.780	53,144.505	0.000*
media	705,630.000	4	176,407.500	7,069.181	0.000*
time	321,646.074	3	107,215.358	4,296.443	0.000*
material* media	216,254.206	4	54,063.551	2,166.490	0.000*
material* time	106,910.376	3	35,636.792	1,428.074	0.000*
medial* time	58,980.824	12	4,915.069	196.962	0.000*
material* media* time	22,423.466	12	1,868.622	74.881	0.000*
Error	3,992.712	160	24.954		
Total	6,587,977.255	200			

Table 14: Three-way ANOVA showing the effect of material, storage media, immersion time and the interaction on fluoride release (ppm) of the studied materials (P<0.05)
*Statistically significant difference at P<0.05

		1 day	3 days	5 days	7 days
IonoGem	Distilled water	80.42 ± 1.8^{a}	49.6 ±1.0^{b}	25.26 ± 0.6^{c}	15.82 ± 1.01^{d}
	Gatorade Perform 02	367.2 ± 7.8^{a}	266.52 ± 6.5^{b}	233.6 ± 5.5^{c}	171.8 ± 4.5^{d}
	Pocari sweat	296 ± 10.6^{a}	197.8 ±16.0^{b}	188.18 ± 12.5^{c}	186.4 ± 4.5^{c}
	Red Bull	428.2 ± 3·2a	283.02 ± 5.^{0}b	259.78 ± 3·8c	193.7 ± 4·5d
	Power Horse	438.2 ± 3.3^{a}	281.8 ± 4.5^{b}	264 ± 4.8^{c}	194.52 ± 3.1^{d}
IonoGem LC	Distilled water	16.08 ± 2.0^{a}	6.34 ± 0.4^{b}	1.76 ± 0.2^{b}	1.63 ± 0.1^{b}
	Gatorade Perform 02	94.88 ± 1.51^{a}	70.4 ± 3.2^{b}	59.88 ± 2.4^{c}	49.12 ± 2.7^{d}
	Pocari Sweat	82.24 ± 3.4^{a}	47.36 ± 1.9^{b}	45.2 ± 4.7^{b}	41.5 ± 3.2^{b}
	Red Bull	106.74 ± 3^{a}	85.94 ± 4.0^{b}	58.92 ± 2.4^{c}	48.38 ± 3.2^{d}
	Power Horse	117.64 ± 3.03^{a}	89 ± 3.3^{b}	62.6 ± 3.3^{c}	51.94 ± 2.9^{d}

Table 15: Means, standard deviations and results of LSD test of fluoride release (ppm) of the studied materials in different media after 1, 3, 5 and 7 days Means with same superscript letters in each raw are not significantly different.

Fracture toughness is a measurement of a material's ability to resist catastrophic failure [20]. Fracture toughness is independent of the size and geometry of the specimen and is a more reliable parameter to predict clinical performance [21]**.** It was noted that the surface hardness values of the composite resin materials were significantly decreased, either immersed in distilled water or immersed in sports and energy drinks after the 1-month evaluation period [22].

The results showed that there was no significant difference in fracture toughness between sport and energy drinks and distilled water after 1 day for both conventional and resin-modified glass ionomer. Whereas, after 7 days, there was a significant difference between conventional glass ionomer specimens immersed in Red Bull and Power Horse and the other storage media, they underwent severe erosion resulting in dissolution of specimens and loss of strength. This may be because both are carbonated drinks which may have more erosive effect on conventional glass ionomer cements with prolonging immersion time. For the other storage media, there was no significant difference between the first and seventh days of immersion. This may be due to the immersion time was not sufficient enough to affect the mechanical properties. Moreau and Xu [23] found that solution pH had little effect on the mechanical properties of resin-modified glass ionomer.

Roughness refers to the surface texture of a material. There are two types: the smoothness resulting from a finishing process, referred to as applied or acquired smoothness, and the smoothness of an unpolished material, referred to as inherent smoothness. Inherent smoothness depends on the filler particle size of the material [24]. Surface roughness assessment is important because it is well documented that surface micro morphology can play a role in bacterial colonization and maturation of plaque on restorative materials [25]. These interactions may predispose a restoration to the development of secondary caries and may lead to periodontal inflammation [26,27].

The results of the current study showed that conventional glass ionomer was rougher in sport and energy drinks than resin-modified glass ionomer. After 1 day of immersion, conventional glass ionomer specimens immersed in sport and energy drinks were rougher than those immersed in distilled water. Whereas, resin-modified glass ionomer specimens immersed in sport and energy drinks were not significantly different from those immersed in distilled water. This indicates that RMGI resist acid better than conventional glass ionomer cement. Hamouda [28] concluded that low pH beverages were the most aggressive media for glass ionomers and compomer, by contrast, composite resin was relatively less affected. Water and natural milk appeared relatively benign towards the tested materials.

Both conventional and resin-modified glass ionomer had more rough surfaces after 7 days. This was owed to these beverages contain citric acid which is carboxylic acid capable of chelating ions present in the cement, such as calcium and forming complexes of reasonable solubility in water [29]. The specimens immersed in Red Bull (pH=3.1) and power horse (pH=2.8) showed more rough surfaces than the specimens immersed in Gatorade (pH=2.8) and Pocari Sweat (pH=3.3) for both conventional and resin-modified glass ionomer. These results showed that mere acidity of the storage medium is not responsible for degradation of the cements.

For the analysis of fluoride released from materials into aqueous solutions, an ion-selective electrode (ISE) or Ion Chromatograph (IC) can be used. Ion Chromatograph was chosen in the current study because this method is suitable for the measurement of not only free fluoride ions but also low concentration of fluoride ions that may not be detected by the ISE method [30]**.** The results of the current study showed that both conventional and resin-modified glass ionomers release more fluoride in acidic beverages than distilled water. This high fluoride release suggests an increase in dissolution of the material and this was observed on the surface roughness [31]. However, conventional glass ionomer released fluoride more than resin-modified glass ionomer. This indicates that RMGI resist acid better than conventional glass ionomer cement. In addition, for both GICs the F released in the first day's immersion is greater than in the following storage days. The high level of F release on the first day may be caused by the initial superficial rinsing effect (independent of time), while the constant F release during the following days occurs because of the ability of fluoride to diffuse through cement pores and fractures [32]. Another explanation is that fluoride release has been attributed to acid-base setting reactions involving fluoride-containing glasses and a polyacid liquid leading to fluoride liberation. A progressive and gradual decrease in release rate of fluoride until the seventh storage day was found for both conventional and resin-modified glass ionomer.

The highest fluoride release among sport and energy drinks was recorded for Red Bull (pH=3.1) and power horse (pH=2.8) and the lowest fluoride release was recorded for Pocari Sweat (pH=3.3). These results are consistent with surface roughness results, that the specimens immersed in Red Bull and Power Horse showed more rough surfaces which indicates more degradation and hence more fluoride release.

Conclusions

Based on the results and within the limitation of this study, the following conclusions can be made:

1. The fracture toughness was not significantly changed after 1 day for both conventional and resin-modified glass ionomer. Whereas, after 7 days, there was a reduction in fracture toughness of conventional glass ionomer in Red Bull and Power Horse.
2. Resin-modified glass ionomer showed better resistance to acidic sport and energy drinks but with prolonged consumption of these drinks, surface smoothness could be affected and thus would affect clinical performance of the filling material.
3. Fluoride release increased with the consumption of sport and energy drinks as the degradation of the glass ionomers increased according to the results of surface roughness.
4. The acidity of sport and energy drinks is not an indicator of the erosive potential. As indicated by the results carbonated energy drinks with similar pH to sport drinks had more erosive effects on glass ionomers. Hence, the erosive potential of drinks may depend on titratable acidity of individual drink or the composition of the drinks.

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