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Evaluation of solubility of resin-modified glass-ionomer cement after immersion in different energy drinks under various modes of light-curing

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Abstract
Background To overcome the traditional problems, including compromised mechanical strength, wear resistance, and aesthetics associated with conventional glass ionomer cement (CGIC) materials, resin-modified glass ionomer cement (RMGIC) was introduced in 1989. RMGIC maintains the clinical advantages of CGIC, such as fluoride release and simplicity in clinical operation, and is more aesthetically pleasing than CGIC.
Aim This study aimed to evaluate the solubility of resin-modified glass ionomer cement in various energy beverages at different modes of curing [soft start, fast, pulse] by charging plug dual-use Ly-B200 light cure device.
Materials and methods 60 standardized discs were fabricated from a resin-modified glass ionomer cement and divided into three main groups according to the type of curing mode 20 each (soft start, fast, and pulse). All specimens were immediately weighed. Four commercially available beverages were used as immersion media. The pH of the beverages was measured using a digital pH meter. Then each main group was divided into four groups according to types of solution: 5 specimens each (High Protein powder, Red bull, Creatine, and C4), then the specimens were dried and weighed again after immersion. The data collected for the specimen's weight before and after immersion in the sport drinking solution were then expressed as mean ± standard deviation and compared between two groups by Student's t-test. A one-way ANOVA was used for multiple group comparisons. ($p < 0.05$).
Results: For all modes of light cure, the highest solubility among the energy beverages was recorded for specimens immersed in Red Bull, while the lowest solubility was recorded when the specimens were immersed in protein powder. The pulse mode recorded the highest solubility in all specimens, while the soft start mode recorded the lowest solubility for all specimens.
Conclusion: This study found that the RMGIC immersed in energy beverages showed more solubility at all time intervals compared to the immersion in distilled water, and the lowest solubility was recorded in RMGIC specimens immersed in protein powder when using the soft start mode of light curing.

Keywords: Glass ionomer cement, solubility, energy beverages

Introduction
Dietary counseling is a crucial part of oral health education programs in modern society. The consumption of carbonated drinks is popular with adolescents, and the habit is carried over into older ages. The popularity of sports energy drinks has raised questions about their erosive potential on the surface hardness of enamel due to their acidity [1]. Dental erosion does not only affect enamel. When reaching dentine, it can cause hypersensitivity, or in severe cases, pulp exposure and even tooth fracture [2, 3].
The clinical performance of restorative filling materials is affected by erosion as well. Studies reported that acidic conditions degraded glass ionomer cement, polyacid-modified resin composites, and restorative composites [4, 5., 6]. Component leaching from luting cement has a significant impact on structural stability and biocompatibility [7, 8, 9].
Solubility also has a considerable impact on the mechanical strength, thermal insulation capabilities, surface texture, and aesthetic properties of luting agents. Solubility is thought to be a risk factor for recurrent caries, pulpal inflammation, postoperative hypersensitivity, and periodontitis [9].
Some of the main factors that cause surface degradation of cements include the pH of the foods and beverages taken by the patient, the composition, and the pH of the saliva. In the oral environment, erosive intensity is modified by the quality and quantity of saliva [10]. Saliva modifies the erosive process. Individuals with low or diminished salivary flow were susceptible to erosive tooth damage [11]. Some tooth-colored restorative materials showed an increase in surface hardness after prolonged immersion in saliva [12].
Glass ionomer cements (GIC) were introduced into clinical practice about 40 years ago, and the significant benefits of their use have made this material a very useful complement to restorative dentistry. Their main characteristics include ion exchange adherence to both dentine and enamel, biocompatibility, and continuous fluoride release throughout the restoration's life [13].
Resin-modified GICs and high-viscosity GICs were developed in an attempt to increase physical qualities while also accelerating the slow-setting reaction, which can compromise early strength and wear [14]. In addition to the glass-ionomer cement, the hybrid cement incorporates organic monomers, namely HEMA (2-hydroxyethyl methacrylate), as well as a photo-sensitive initiator system that allows the cement to be cured under blue light [14].

It is very important to achieve adequate polymerization of the resinous component to ensure basic mechanical properties and longevity of restorations [15]. Polymerization effectiveness is influenced by the type of light curing unit (LCU), its irradiance, and exposure time [16].
Nowadays, different types of LCUs are being used for the polymerization of light-activated resinous materials [17], and halogen and light-emitting diode light curing units (LED LCU) are the most commonly used "third generation" of LED LCUs, which generate multiple wavelengths the "third generation" of LED LCUs, which generates multiple wavelengths, is particularly effective for polymerization of any type of dental restorative material [17].
LEDs hold several advantages over halogen-based units, including having longer lifetimes of several thousand hours, converting electricity to light more efficiently, producing less heat, not requiring filters, and having resistance to shock and vibration [18].
There are different polymerization modes of LED lamps that can influence the resin-modified glass ionomer cement polymerization reaction [19]. A standard mode uses a high initial intensity of light and provides a higher degree of depth of polymerization [20]. This mode can induce higher shrinkage stress during the curing [21]. High power density modes are characterized by the activation of a large number of photoinitiated molecules at the same time, which will produce more inner stresses [22]. Gradual polymerization modes have been introduced to minimize polymerization shrinkage and consequent microleakage [22].
These cements are indicated especially for performing Atraumatic Restorative Treatment (ART), and favorable results concerning their physical properties have been documented. Nevertheless, reports have suggested that the newer more-viscous GICs and resin-modified GICs release considerably less cumulative fluoride ions than less-viscous aesthetic restoratives [23].
Although remineralization ability to surrounding enamel has been confirmed by GIC under an acidic attack after cariogenic challenge [8], there is little evidence about the influence of their properties concerning an erosive challenge [23].
Furthermore, there are few studies about resin-modified glass ionomer cement, considering both the erosive challenge with the consumption of different energy beverages under different modes of light-curing.

Aim of the study:
The aim of this *in vitro* study was to investigate the solubility of resin-modified glass ionomer when immersed in different sports energy beverages (Red bull, Creatine, Whey Protein powder, C4) under different modes of light curing (soft start, fast, and pulse).

Material and Method

A. preparation of sporting immersion solution
The RMGIC specimen was stored in plastic tubes with 4 mL of drinking solution, which included the following: Red bull, hey protein immersion solution (we mix 30.4 g of Whey protein powder with 263.5 ml of water and then mix for 30 seconds), in case of C4 (we mixed 7.1 g of C4 powder with 263.5 ml of water and mixed for 30 seconds), and creatine (5 g of creatine powder mixed with 236.5 ml of water for 30 seconds) according to manufacture instructors.

B. Preparation of resin-modified GIC specimens
60 specimens of visible-light-activated resin (Riva Light Cure) were prepared following the manufacturer's recommendations and then condensed the GIC capsules into a circular split Teflon mold (5 mm in diameter and 2 mm thickness) against a glass slab in a bulk technique.

Then glass plates were forced against all of the specimens with heavy weights to smoothen their top surfaces as well as to prevent air inhibition during curing. The specimens were cured using a visible-light cured unit (charging plug dual use LY-B200, China), which was applied in various directions with light intensity at 400 mW/cm2 for 20 seconds each to the specimen.
This process was repeated immediately after the plate removal. All cures were done at room temperature. Then, the specimens were stored at 37°C for 24 h (by manufacture manual).
The specimens were divided into three main groups according to the type of curing mode (20 seconds each) (soft start, fast, and pulse).

C. Curing protocols
Above the specimen, each experimental group was illuminated with one of the following light-curing modes for 20 s: pulse (650 mW/cm2), soft (650-1100 mW/cm2), and fast (1100 mW/cm2). Specimen preparation was performed at room temperature, while subsequent aging was simulated by the storage at 37±1°C in drinking solution in an incubator (Cultura, Ivoclar-Vivadent, Schaan, Liechtenstein) for one month.

The soft start technique has low initial intensity (650 mW/cm2) in the few first seconds, followed by full intensity (1100 mW/cm2). This reduces polymerization stress by inducing the glass ionomer to flow in the gel state [24, 25].
The pulse-activated polymerization uses short impulses of high intensity (e.g., e-light b: 10 pulses for 2 seconds each 650 mW/CM2 [25].
The fast mode technique, the glass ionomer, is cured at a continuous high intensity of light (1100 mW/cm2), providing a higher degree of monomer conversion.
All specimens were weighed with precision by digital balance (hettich), and the weight was recorded with a maximum weight variation of ± 0.0005 g.
The RMGIC specimens were stored in plastic tubes containing 4 ml of each examined energy drinking solution.
The specimens were centrifuged for 15 minutes at a speed of 3000 RPM for 15 seconds. This procedure was repeated for 3 days weekly for one month. The specimens were kept in a drinking solution during storage time (for 1 month).

Table 1: Represent the common product brand and pH of the drinking solution used in this study

	Brand	PH	Components
Whey Protein Isolate Powder	Optimum Nutrition	6	Total fat (1.5 g) Cholesterol(55mg) Total protein(24g) Total carbohydrates(3g) Total sugars(1g) Calcium(130mg) sodium(130mg) Iron(0.7mg) Potassium(200mg)
Energy drink	Red Bull	3.24	Total fats(0mg) sodium(0.1mg) Total carbohydrates(27g) protein(0g)

			Niacin (20 mg), Pantothenic Acid (5 mg), vitamin B6 (5 mg), vitamin B12 (5 ug), Caffeine (80 mg)
Pre-workout C4	Cellucor	3.8	Calories (5) Total Carbohydrate (0 g) Total Fat(0g) Total Sugars (0 g) niacin(30mg) vitamin B12 (6mcg) Calcium(25mg) Sodium(0mg) Potassium(85mg) Caffeine(200mg)
Creatine	Dexter Jackson	5.8	Creatine monohydrate

Results

- The collected data concerned with the mean score of resin-modified glass ionomer cement specimens' weight are listed in table (1) and illustrated graphically in figure (1,2.3). These results were analyzed statistically using ANOVA and the Student's t test, and the level of significance was taken at $p < 0.05$.

Table 2: The collected mean score of RMGIC specimens weight before and after the immersion in the various energy solutions under different light cure modes

Drinking sol. / Mode	Red bull		Sport drink C4		Creatine		Protein powder	
	Before immersion	**One month after**	**Before immersion**	**One month after**	**Before immersion**	**One month after**	**Before immersion**	**One month after**
Pulse	44.3	42.4	45.4	43.7	44.1	42.7	46.4	45.2
Fast	43.8	42.2	45.6	44.4	44.8	43.6	43.4	42.6
Soft start	42.8	41.6	43.6	42.6	44.6	43.8	44.2	43.6

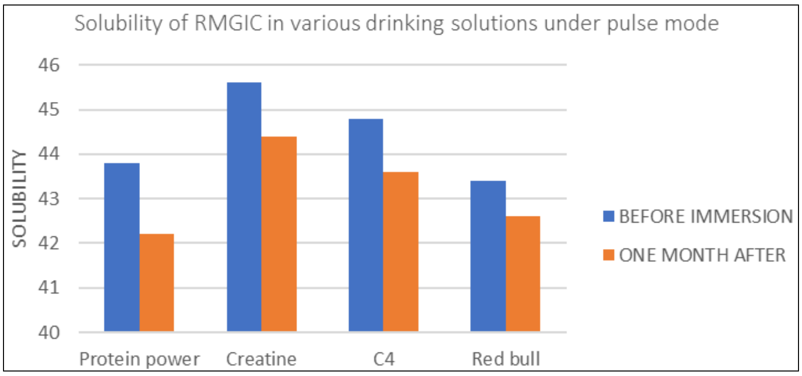

Fig 1: Histogram of the mean score (5 specimens) of RMGIC specimens before and after immersion in various drinking solutions using pulse curing mode

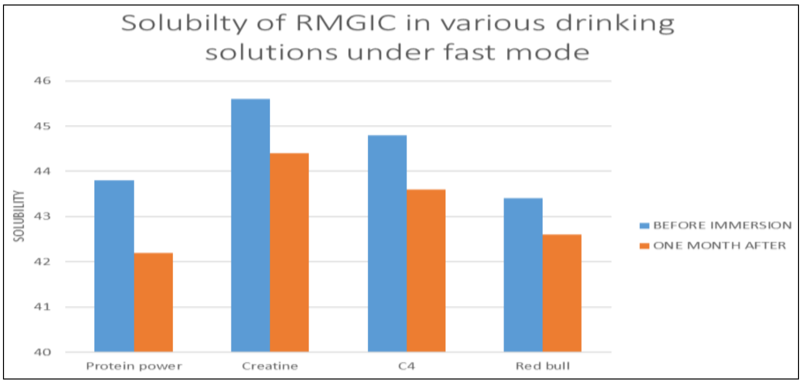

Fig 2: Histogram of mean score (5 specimens) of RMGIC specimens before and after immersed in various drinking solutions using different fast curing modes

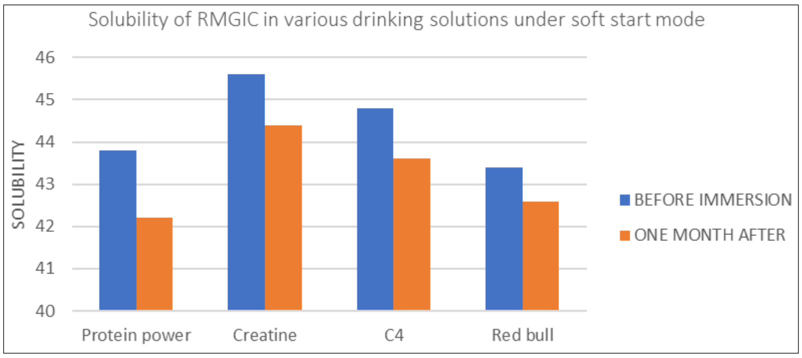

Fig 3: Histogram of mean score (5 specimens) of RMGIC specimens before and after immersion in various drinking solutions using different soft start curing modes

- All the specimens recorded solubility.
- For the energy drinking, the highest solubility was recorded for specimens immersed in red bull, while the lowest solubility was recorded when the specimens were immersed in protein powder.
- For the modes of light curing, the pulse mode recorded the highest solubility in all specimens of all sport drinking solutions, while the (soft start) mode recorded the lowest solubility for all specimens.
- There is no significant difference between all the modes.

Discussion

This study compares the acid solubility of RMGIC on exposure to four different energy drinks at three different curing modes. The study suggests that assessing weight change after three days of exposure to acidic solutions is a simple screening method. This is because any highly soluble materials will have dissolved into the acid and can be visually assessed before weighing. The differences among the study groups are likely due to changes in particle chemistry and material properties, resulting in faster setting times and increased strength.

When the restorative materials are exposed to or stored in water, two different mechanisms occur. First, there will be uptake of water producing an increased weight (sorption) and leaching or dissolution of components from the material into the mouth (solubility), leading to a reduction in weight [26].

The increase in the surface solubility Ra of RMGIC materials is related to the resin filler type, type of resin matrix [27], type of solution, presence of acids in the GIC, and aging time the pH value of the environment can also influence solubility [29].

Red Bull exhibited the highest solubility, possibly due to its pH around 2.5, making it more acidic than other types of solutions. This higher acidity contributes to increased solubility and discoloration effects on all specimens compared to other solutions. RMGICs are highly soluble in low pH solutions, leading to matrix softening, surface abrasion, and loss of structural ions. The acids in energy drinks can penetrate the resin matrix, accelerating the release of unreacted monomers by reducing surface hardness [30].

Materials that absorb water can also absorb other acidic fluids with pigments, leading to surface degradation. Water acts as a conductor for acidic penetration into the resin matrix. While the resin matrix can absorb water, inorganic glass fillers can only absorb water on their surface. Excessive water sorption may decrease the lifespan of a resin GIC by expanding and plasticizing the resin component, hydrolyzing the silane, and causing microcrack formation. Micro-cracks or interfacial gaps between the filler and matrix allow for surface degradation and penetration of acid and other liquid solution components, increasing surface roughness (Ra) [31, 32].

Different curing modes of LED light are used for the polymerization of dental RMGIC, such as high mode, normal mode, low mode, soft-start mode, and pulse mode, which may have varying effects on the mechanical and physical properties of the RMGIC material [33].

The soft-start mode exhibited the lowest solubility with RMGIC specimens [29, 34], while the pulse mode showed the highest solubility. In the soft-start curing mode, the RMGIC is initially cured at low intensity and then stepped up to a high-intensity light to reduce polymerization stresses by inducing the RMGIC to flow in the gel state during the first application, facilitating some degree of shrinkage stress relaxation. Soft-start polymerization is believed to partially relieve shrinkage stresses and improve the marginal integrity of the restoration [29, 35, 36].

On the contrary, other studies have found that the degrees of conversion and microhardness of RMGIC are not affected by various modes of LED curing lights [3, 28, 37]. Therefore, more research is needed in this field.

Conclusion

Under the conditions of this *in vitro* study, it can be concluded that the material is affected by immersion in all solutions (solubility). The lowest solubility for RMGIC specimens was observed when immersed in protein powder using the soft-start mode, while the highest solubility was recorded for RMGIC specimens when immersed in Red Bull and using the pulse mode.

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