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Solubility of glass ionomer cement in various acidic beverages at different time intervals: an *in vitro* study

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Abstract

Background: Glass Ionomer is a widely used cement in dentistry for luting and restoration purposes. This cement leaches a large amount of fluoride ions leading to an increase in the early solubility and disintegration in the oral fluids. The solubility of the cement is further aggravated when it is exposed to an acidic medium.

Aim: This study aimed to evaluate the solubility of glass ionomer cement (GIC) in various acidic beverages at different time intervals.

Materials and Methods: Four commercially available beverages and distilled water was used as immersion media. The pH of the beverages was measured using a digital pH meter. Glass ionomer cement discs were prepared and immersed in beverages for 1 day, 24 hours and 7 days. After completing the immersion time in each beverage for a specific period, the specimens were retrieved and weighed. The solubility was calculated by subtracting the weight at the specific immersion period from the initial weight of the specimen.

Results: Immersion in distilled water demonstrated less solubility compared to immersion in acidic beverages. Among the acidic beverages, GIC immersed in MAAZA showed the maximum solubility compared to the other beverages. One-Way ANOVA displayed a significant difference (p=0.000) among the beverages at different time intervals.

Conclusions: This study found that the GIC immersed in fruit juices with preservatives showed more solubility at all time intervals compared to the immersion in carbonated drinks.

Keywords: Glass ionomer cement, Solubility, pH, Acidic beverages.

1. Introduction

Dental cements are used as luting agents and restorative materials in the oral cavity. The major purpose of the development of dental cement is to permanently retain metallic and non-metallic restorations such as inlays, crowns, and bridges to the prepared tooth structure. Other applications of dental cements include bonding of orthodontic appliances to the teeth and cementing pins and posts to retain restorations [1-7]. Solubility and disintegration (SD) of a dental cement in saliva or other fluids taken by the patient play a significant role in the durability of luting agents. The hydrolytic breakdown of cements in oral fluids causes the release of some important constituents, debonding of the restoration, and the possibility of microleakage and recurrent decay. Component leaching from luting cements has a significant impact on structural stability and biocompatibility [2,8,9]. Furthermore, SD has a significant impact on the mechanical strength, thermal insulating capability, surface texture, and aesthetic qualities of luting agents. SD is believed to be a contributing factor for recurrent caries, pulpal inflammation, post-operative hypersensitivity, and periodontal disease.

Various factors that cause SD of cements include composition of the cements, less powder-liquid ratio, the release of fluoride ions from certain cements, oral hygiene maintenance by the patient, composition of the dentifrice, pH of the foods/beverages taken by the patient, composition and pH of the saliva [9]. Numerous studies reported that the acidic pH increases SD to a greater extent [10-12]. Therefore, it is evident that the SD is more among the patients consuming more acidic beverages. This can be attributed to the decrease in pH of the saliva that results in the hydrolytic breakdown of cements in oral fluids and is also due to the release of protic acids from the beverages. Furthermore, if the saliva is maintained at lower pH for a long time may also result in increasing SD.

Glass Ionomer Cement (GIC) is one of the most commonly used cements for various applications in dentistry due to its anticariogenic property and chemical adhesion to the natural tooth [1-3, 8]. However, GICs usually exhibit high solubility and disintegration in the oral fluids especially immediately after their placement due to the leaching out of a large amount of fluoride ions. This SD may increase when the pH of the oral cavity is reduced.

Carbonated soft drinks and various fruit juices with preservatives have very less pH and consumption of these may increase the solubility of disintegration of luting agents. However, limited literature is available on the effect of carbonated soft drinks on the solubility and disintegration of luting agents. Hence, this study focused to evaluate the SD of dental luting agents in various carbonated soft drinks and fruit juices with preservatives.

2. Materials and methods

Type-II Glass Ionomer cement (GC Corporation, Tokyo, Japan) and four commercially available luting agents, two carbonated soft drinks and two fruit juices with preservatives were used in this study. The carbonated soft drinks were Thums Up, and Sprite, whereas fruit juices with preservatives were Appy and MAAZA.

A total of 50 GIC discs were prepared in a metal mold with an inner diameter and thickness of 10x2 mm respectively. Ten specimens (n=10) were allocated to each beverage and distilled water was used for the control group. The GIC powder and its respective liquid were proportioned as per the manufacturer's recommendations and were mixed until the appropriate consistency was obtained. The cement mix was packed into the metal moulds and the cement was covered with slide-fixing glasses on either side of the metal moulds to ensure smooth surfaces and a load of 100 grams was applied until the material was set.

The pH of the beverages was measured using a digital pH meter (Li 120, Elico). The solubility of the GIC discs was assessed using a weight loss method after immersing the specimens in various beverages at different time intervals. The initial weight of prepared discs was taken at regular intervals until a constant mass was attained using precision balance and it was recorded as W1. Then, the specimens were transferred into their labelled bottles and 20 ml of beverage was added and stored in an incubator at 37°C for 1 hour. After 1 hour, the specimens were retrieved from the incubator and the excess solution was removed followed by drying the specimens at room temperature. The weight of the specimens was recorded as W2. The specimens were placed again in their respective clean labelled bottles and 20 ml of beverage was added and stored in an incubator at 37°C for 24 hours. After 24 hours, and 7 days the same process that was described for W2 was used and the weight of the specimens was recorded as W3 and W4, respectively. The Solubility of the specimens at different time intervals was measured using the following formula.
Solubility after 1 hr immersion W5=W1-W2
Solubility after 24 hours immersion W6=W1-W3
Solubility after 7 days immersion W7=W1-W4

The obtained data were subjected to statistical analysis using SPSS for Windows, Version21.0, SPSS Inc., USA. One-way ANOVA and posthoc Tukey tests were used for inter-group and intragroup comparisons respectively.

3. Results

The pH of various beverages was given in table 1. Thums Up displayed the least pH among the beverages studied. However, all the beverages used in the study showed less pH except distilled water (Table 2). Means and standard deviations of solubility and disintegration of various luting agents in different acidic beverages at 1 hour, 24 hours, and 7 days immersion are given in Table 2.

Table 1. pH of the beverages used in the study

Beverages	Distilled water	Thums Up	Sprite	MAAZA	Appy
pH	7.0	1.81	2.22	3.03	2.86

Immersion of the GIC in distilled water exhibited the least solubility at different time intervals compared to immersing in acidic beverages. The GIC specimens immersed in MAAZA displayed the highest solubility. An increase in the solubility was observed among the specimens in all the beverages with increasing in immersing time, i.e., from 1 hour after mixing to seven days (Figure 1). Oneway ANOVA showed a significant difference (p=0.000) in the solubility of GIC in various beverages at different time intervals (Table 2).

In a post-hoc analysis, immersion in distilled water showed significant differences with the acidic beverages at different time intervals except with the Thums Up (p=0.492) at one-hour immersion. Among the acidic beverages, GIC immersion in Thums Up displayed a significant difference with the other acidic beverages at all time intervals except with Sprite at 24 hours (p=0.064). MAAZA displayed significant differences with Sprite and Appy at all time intervals of immersion except at 1 hour with Appy (p=0.090). however, Sprite did not show significant differences with Appy at all time intervals (Table 3).

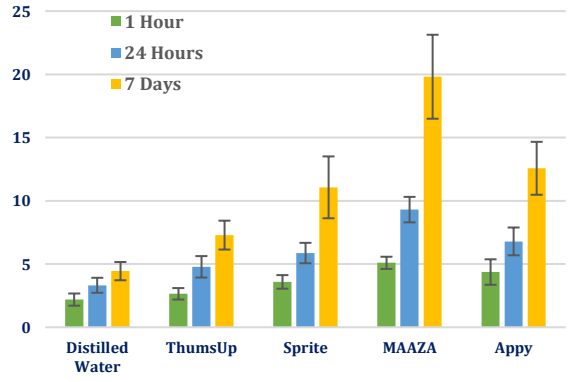

Figure 1: Solubility (µg/mm²) of Glass Ionomer Cement in various acidic beverages at different time intervals.

4. Discussion

An ideal dental cement should have high resistance to dissolution in oral fluids. Numerous factors influence the solubility and disintegration of dental cements in the oral cavity, such as saliva concentration and pH, exposure time to saliva and other beverages, and the cement's powder-liquid ratio [2]. Various *in vitro* studies evaluated the performance of dental cements using water, acids, and other solvents to simulate the contaminating environment of the mouth [13-16]. In *in-vitro* studies, the chemical composition of the solutions plays a vital role in assessing the durability of dental cements as it should simulate the complexity of the oral environment. Further, the time of immersion also affects the physical and mechanical properties of dental cements [17,18].

Table 2: Mean solubility and standard deviations (SD) of glass ionomer cement immersed in different beverages at different time intervals (One-way ANOVA)

Beverages	1 hour immersion		24 hours immersion		7 Days immersion	
	Mean ± SD	Significance	Mean ± SD	Significance	Mean ± SD	Significance
Distilled Water	2.1890±0.482	0.000	3.3210±0.592	0.000	4.4380±0.722	0.000
Thums Up	2.6450±0.453		4.7800±0.848		7.2870±1.143	
Sprite	3.5860±0.538		5.8680±0.807		11.0640±2.446	
MAAZA	5.0940±0.482		9.3020±1.009		19.8100±3.320	
Appy	4.3660±1.008		6.7890±1.099		12.5690±2.093	

Table 2. Inter-group comparison of solubility of GIC in various acidic beverages at different time intervals.

Beverages		1 hour		24 hrs		7 days	
		Mean Difference ± Standard error	Significance	Mean Difference ± Standard error	Significance	Mean Difference ± Standard error	Significance
Distilled water	**Thums Up**	0.45600±0.281	0.492	1.45900*±0.397	0.006	2.84900*±0.964	0.038
	Sprite	1.39700*±0.281	0.000	2.54700*±0.397	0.000	6.62600*±0.964	0.000
	Appy	2.17700*±0.281	0.000	3.46800*±0.397	0.000	8.13100*±0.964	0.000
	MAAZA	2.90500*±0.281	0.000	5.98100*±0.397	0.000	15.37200*±0.964	0.000
Thums Up	**Sprite**	0.94100*±0.281	0.014	1.08800±0.397	0.064	3.77700*±0.964	0.003
	Appy	1.72100*±0.281	0.000	2.00900*±0.397	0.000	5.28200*±0.964	0.000
	MAAZA	2.44900*±0.281	0.000	4.52200*±0.397	0.000	12.52300*±0.964	0.000
Sprite	**Appy**	0.78000±0.281	0.059	0.92100±0.397	0.158	1.50500*±0.964	0.529
	MAAZA	1.50800*±0.281	0.000	3.43400*±0.397	0.000	8.74600**±0.964	0.000
Appy	**MAAZA**	0.72800±0.281	0.090	2.51300*±0.397	0.000	7.24100*±0.964	0.000

Several studies reported that the long-term exposure of dental cements to an aqueous environment caused absorption of the fluids that resulted in deteriorating their physical and mechanical properties. The absorbed fluid could act as a plasticizer, which encourages erosion and disintegration of the cement in those fluids resulting in a decrease in its strength [19]. In the present study, the powder-liquid was proportioned based on manufacturer recommendations. This study evaluated the effect of immersing GIC in various acidic beverages at different time intervals on solubility.

In the present study, the GIC immersed in various pH media exhibited solubility at different time intervals. Among the different beverages, immersion in acidic beverages displayed more solubility compared to immersion in distilled water (Figure 1). This increase in the solubility of GIC in acidic beverages can be attributed to their low pH. It was reported in the literature that the solubility of the cements increased when exposed to solutions with a lower pH [10,11]. The findings of this study were in accordance with the study conducted by Walls et al. (1988) [12]. They prepared artificial salivae with different pH and evaluated the solubility of the cements. They observed the highest solubility at a pH of 4 and no solubility in a buffer solution at a pH of 10 after 24 hours. Further, they found that the experimented cements exhibited maximum solubility in artificial saliva at 28 hours at a pH of 3. Similarly, in the current study, the solubility of the GIC was increased as the specimens were aged up to 7 days. GIC exhibited maximum solubility after 7 days of immersion in various pH beverages.

Among the various acidic beverages used, immersion in MAAZA displayed more solubility at different time intervals followed by immersion in Appy, Sprite, and Thums Up (Figure 1). The reason for an increase in solubility after immersing in MAAZA and Appy solutions could be the composition of those beverages. They contain citric acid and at lower pH, these materials increase the solubility of cement. Solubility by citric acid can be due to a reaction of the substrate with the H+ ions of the acid or also to chelation by citrate ions [15,20]. In the current study, MAAZA had a pH of around 3 and all other beverages displayed a much lesser pH compared to MAAZA (Table 1). But the maximum solubility was observed in solutions with an approximate pH value of 3. A decrease in the solubility was observed with a decrease in pH. The reason for this could be the composition of the various beverages used. The presence of citric acid encourages more solubility and erosion of dental cements. After 7 days of immersion, the GIC specimens showed the greatest solubility in the MAAZA compared to other beverages. In this study, the fruit juices demonstrated more solubility, and the reason could be the presence of citric and lactic acids.

The other factors that influence the solubility are the powder-liquid ratio and immersion time. More the powder-liquid ratio lesser is the solubility of the cements [2,3]. However, the powder-liquid ratio used in this study was as per the manufacturer's recommendations. Literature reported that the longer the immersion time greater will be the solubility and disintegration of dental cements in solutions. This study also demonstrated greater solubility in various beverages over 7 days.

Restorative cements are constantly exposed to oral fluids at physiological temperatures in the oral cavity. GIC is sensitive to erosion, and it is probably due to the hydrolysis of some of its constituents. The erosion is exacerbated in the mouth due to the presence of different components in saliva [15]. GIC's clinical success relies upon the early protection from both hydration and desiccation of the cement. Early exposure to moisture and ambient conditions may lead to desiccation and produces contraction. In addition, it may also encourage crazing of the restoration [21].

The current study demonstrated an increased solubility of GIC in various acidic beverages and it is directly

proportioned to the immersion time. However, this is an *in vitro* study, and it allows only static solubility testing as it does not simulate the pH and temperature changes of the oral cavity [13,14,17,18]. Clinical conditions vary, even within the same patient, making it virtually impossible to reproduce a natural environment [19]. The present study was conducted at a maximum of 7 days' time intervals and did not experiment with artificial saliva. The beverages were replaced for every 24 hours. Further studies may focus on increasing the immersion time and including artificial saliva as one of the solutions.

5. Conclusion

Selection of the most suitable restorative material is important, for the longevity of the restoration. Statistically significant differences in solubility were found among the specimens stored in acidic beverages at different time intervals. It was observed that the GIC was more soluble in the acidic medium, and an increase in the solubility was observed with an increase in immersion time.

Conflicts of interest: Authors declared no conflicts of interest.

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