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ORIGINAL ARTICLE

Evaluation of fluoride release and recharge potential of various types of glass ionomer cements

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Lovely Yeasmin[1], Mt. Ummay Salma[2], Dilruba Binte Mostafa[3], Mohammad Mahbub-Ul-Alam[4], Sayma Shahadat[5]

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Correspondence to
Lovely Yeasmin

ABSTRACT

Background: *Fluoride release from glass ionomer cements (GICs) plays a crucial role in preventing secondary caries by enhancing remineralization and inhibiting demineralization. The ability of GICs to undergo fluoride recharge further prolongs their cariostatic effect. This study aimed to evaluate and compare the fluoride release and recharge potential of different types of GICs under standardized laboratory conditions.* ***Methods & Materials:*** *An in-vitro experimental study was conducted in the Department of Science of Dental Materials, Dhaka Dental College, Dhaka, from 1 July 2024 to 30 June 2025. A total of 110 standardized specimens were prepared from conventional GIC (n = 37), resin-modified GIC (n = 36) and high-viscosity GIC (n = 37). Fluoride release was measured at 24 hours, 7 days, 14 days and 28 days using a fluoride ion-selective electrode. After baseline assessment, all specimens underwent fluoride recharge using a fluoridated toothpaste solution and post-recharge fluoride release was measured at the same intervals.* ***Results:*** *High-viscosity GIC showed the highest initial fluoride release (8.60 ± 1.05 ppm at 24 hours) and cumulative fluoride release up to 28 days (20.45 ± 2.10 ppm), followed by conventional GIC and resin-modified GIC. Post-recharge, high-viscosity GIC again exhibited the greatest fluoride release (7.20 ± 0.89 ppm at 24 hours). All differences among groups were statistically significant (p < 0.001).* ***Conclusion:*** *High-viscosity glass ionomer cement demonstrated superior fluoride release and recharge potential compared to conventional and resin-modified GICs, highlighting its suitability for patients with high caries risk.*

Keywords: *Fluoride release, Fluoride recharge, Glass ionomer cement, High-viscosity GIC, Resin-modified GIC, Dental materials.*

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1. *Associate Professor, Department of Science of Dental Materials, Dhaka Dental College, Dhaka, Bangladesh (ORCID: 0009-0000-8021-687X)*
2. *Assistant Professor, Department of Science of Dental Materials, Dhaka Dental College, Dhaka, Bangladesh (ORCID: 0009-0005-4816-5597)*
3. *Assistant Professor, Department of Science of Dental Materials, Rangpur Medical College, Rangpur, Bangladesh (ORCID: 0009-0003-8415-9675)*
4. *Assistant Professor, Department of Prosthodontics, Shaheed Suhrawardy Medical College, Dhaka, Bangladesh (ORCID: 0009-0006-0851-8463)*
5. *Associate Professor, Department of Periodontology, Sylhet MAG Osmani Medical College, Sylhet, Bangladesh (ORCID I'D: 0009-0002-7552-7635)*

INTRODUCTION

Dental caries remains one of the most prevalent chronic oral diseases worldwide, affecting individuals of all age groups despite significant advances in preventive and restorative dentistry [1]. The success of restorative materials is not solely dependent on their mechanical properties but also on their ability to contribute to the prevention of secondary caries [2]. Among the various restorative materials available, glass ionomer cements (GICs) have gained widespread acceptance due to their unique properties, including chemical adhesion to tooth structure, biocompatibility, thermal compatibility with dental tissues and the ability to release fluoride ions [3]. The fluoride-releasing property of GICs plays a crucial role in inhibiting demineralization, enhancing remineralization and suppressing the activity of cariogenic bacteria, thereby reducing the risk of recurrent caries around restorations [4].

Fluoride release from glass ionomer cements typically follows a characteristic pattern, with an initial burst release occurring during the early setting phase, followed by a sustained but gradually decreasing release over time [5]. This prolonged fluoride availability in the oral environment is considered beneficial for long-term caries prevention. However, the amount of fluoride released varies depending on the composition, setting reaction and microstructure of the material [6]. Over the years, several modifications of conventional glass ionomer cement have been developed to improve physical and esthetic properties, resulting in different categories such as resin-modified glass ionomer cements and high-viscosity glass ionomer cements [7]. These material variations may influence both the fluoride release and fluoride recharge capabilities.

An important and clinically relevant characteristic of glass ionomer cements is their ability to undergo fluoride recharge [8]. Fluoride recharge refers to the capacity of a restorative material to absorb fluoride ions from external sources, such as fluoridated toothpaste, mouth rinses, or professional topical fluoride applications and subsequently release them over time [9]. This property enables glass ionomer cements to act as a fluoride reservoir, thereby prolonging their cariostatic effect even after the initial fluoride release has diminished [10]. The extent of fluoride recharge and subsequent re-release depends on factors such as material composition, porosity and the hydrophilic nature of the cement matrix.

Despite extensive use of glass ionomer cements in clinical practice, comparative data on fluoride release and recharge potential among different types of GICs remain variable. Understanding these differences is essential for appropriate material selection, particularly in patients with high caries risk. Therefore, the present study was undertaken to evaluate and compare the fluoride release and fluoride recharge potential of various types of glass ionomer cements under standardized laboratory conditions. The findings of this study are expected to provide valuable insights into the fluoride-releasing behavior of different GICs and assist clinicians in making evidence-based decisions regarding restorative material selection.

METHODS & MATERIALS

This in-vitro experimental study was conducted in the Department of Science of Dental Materials, Dhaka Dental College, Dhaka, over a period of one year, from 1 July 2024 to 30 June 2025. A total of 110 standardized specimens were prepared to evaluate and compare the fluoride release and fluoride recharge potential of various types of glass ionomer cements. The glass ionomer cements included conventional glass ionomer cement, resin-modified glass ionomer cement and high-viscosity glass ionomer cement. All materials were handled and mixed strictly according to the manufacturers' instructions. Standardized cylindrical specimens measuring approximately 6 mm in diameter and 2 mm in thickness were fabricated using stainless steel molds to ensure uniformity. After initial setting, the specimens were carefully removed from the molds and finished using fine polishing discs. Each specimen was stored individually in sealed containers containing deionized water and maintained at 37°C throughout the study period. Fluoride release was measured at predetermined time intervals of 24 hours, 7 days, 14 days and 28 days, with the storage medium being replaced at each interval. The collected solutions were analyzed for fluoride concentration using a fluoride ion-selective electrode after the addition of total ionic strength adjustment buffer (TISAB) to ensure accurate measurement. Following baseline fluoride release assessment, a fluoride recharge protocol was performed by exposing the specimens to a fluoridated toothpaste solution for a standardized duration, after which they were rinsed and re-immersed in deionized water. Post-recharge fluoride release was measured using the same methodology and time intervals. The collected data were compiled and statistically analyzed using SPSS software, with results expressed as mean and standard deviation and a p-value less than 0.05 was considered statistically significant.

RESULTS

Table I shows the distribution of specimens according to the type of glass ionomer cement used in the study. Out of a total of 110 specimens, 37 (33.6%) were prepared from conventional glass ionomer cement, 36 (32.7%) from resin-modified glass ionomer cement and 37 (33.6%) from high-viscosity glass ionomer cement, indicating an almost equal distribution of specimens among the three study groups.

Table – I: Distribution of Specimens According to Type of Glass Ionomer Cement (*n* = 110)

Type of Glass Ionomer Cement	Number of Specimens (n)	Percentage (%)
Conventional GIC	37	33.6
Resin-Modified GIC	36	32.7
High-Viscosity GIC	37	33.6
Total	110	100

Table II presents the mean fluoride release (ppm) at different time intervals among the different types of glass ionomer cements. At 24 hours, the highest fluoride release was observed in high-viscosity GIC (8.60 ± 1.05 ppm), followed by conventional GIC (7.85 ± 0.92 ppm) and resin-modified GIC (6.20 ± 0.81 ppm). A gradual reduction in fluoride release was noted over time across all groups; however, high-viscosity GIC consistently demonstrated higher fluoride release at 7 days (5.30 ± 0.76 ppm), 14 days (3.85 ± 0.64 ppm) and 28 days (2.70 ± 0.51 ppm). The differences in fluoride release among the groups at all time intervals were statistically significant ($p < 0.001$).

Table – II: Mean Fluoride Release (ppm) at Different Time Intervals Among Different Types of GICs

Type of GIC	24 Hours (Mean ± SD)	7 Days (Mean ± SD)	14 Days (Mean ± SD)	28 Days (Mean ± SD)
Conventional GIC	7.85 ± 0.92	4.62 ± 0.71	3.12 ± 0.58	2.05 ± 0.44
Resin-Modified GIC	6.20 ± 0.81	3.85 ± 0.63	2.48 ± 0.52	1.60 ± 0.39
High-Viscosity GIC	8.60 ± 1.05	5.30 ± 0.76	3.85 ± 0.64	2.70 ± 0.51
p-value	<0.001	<0.001	<0.001	<0.001

Table III demonstrates the cumulative fluoride release up to 28 days among the different types of glass ionomer cements. The highest cumulative fluoride release was observed in high-viscosity GIC (20.45 ± 2.10 ppm), followed by conventional GIC (17.64 ± 1.86 ppm), while resin-modified GIC showed the lowest cumulative fluoride release (14.13 ± 1.54 ppm). The difference in cumulative fluoride release among the three groups was statistically significant ($p < 0.001$).

Table – III: Cumulative Fluoride Release (ppm) up to 28 Days Among Different GICs

Type of GIC	Cumulative Fluoride Release (Mean ± SD)	p-value
Conventional GIC	17.64 ± 1.86	
Resin-Modified GIC	14.13 ± 1.54	<0.001
High-Viscosity GIC	20.45 ± 2.10	

Table IV shows the mean fluoride release after fluoride recharge at different time intervals for the various glass ionomer cements. At 24 hours following recharge, high-viscosity GIC exhibited the highest fluoride release (7.20 ± 0.89 ppm), followed by conventional GIC (6.40 ± 0.78 ppm) and resin-modified GIC (4.85 ± 0.69 ppm). A gradual decline in fluoride release was observed at 7 days, 14 days and 28 days in all groups; however, high-viscosity GIC consistently demonstrated higher fluoride release values at each interval. The differences in post-recharge fluoride release among the groups at all time points were statistically significant ($p < 0.001$).

Table – IV: Mean Fluoride Release (ppm) After Fluoride Recharge at Different Time Intervals

Type of GIC	24 Hours	7 Days	14 Days	28 Days
Conventional GIC	6.40 ± 0.78	4.15 ± 0.66	2.90 ± 0.55	1.95 ± 0.42
Resin-Modified GIC	4.85 ± 0.69	3.10 ± 0.58	2.05 ± 0.47	1.45 ± 0.36
High-Viscosity GIC	7.20 ± 0.89	4.95 ± 0.72	3.55 ± 0.61	2.40 ± 0.48
p-value	<0.001	<0.001	<0.001	<0.001

DISCUSSION

The present in-vitro study evaluated the fluoride release and fluoride recharge potential of different types of glass ionomer cements and demonstrated significant differences among conventional glass ionomer cement, resin-modified glass ionomer cement and high-viscosity glass ionomer cement. An almost equal distribution of specimens was ensured among the three groups, with conventional GIC and high-viscosity GIC each comprising 33.6% and resin-modified GIC comprising 32.7% of the total samples, allowing valid comparison across groups. The findings revealed that high-viscosity GIC consistently exhibited superior fluoride release and recharge capacity compared to the other materials tested.

In the present study, all glass ionomer cements showed a characteristic initial burst of fluoride release at 24 hours, followed by a gradual decline over time. High-viscosity GIC demonstrated the highest fluoride release at 24 hours (8.60 ± 1.05 ppm), while resin-modified GIC showed the lowest (6.20 ± 0.81 ppm). This pattern aligns with findings reported by Kosior et al., who observed greater fluoride release from conventional and high-fluoride ionomer materials compared to resin-modified systems, attributing this to differences in matrix composition and ion mobility [11]. Similarly, Khadatkar et al. reported significantly higher early fluoride release from high-viscosity and conventional GICs than from resin-based materials, supporting the results of the present investigation [12].

The sustained fluoride release observed over 7, 14 and 28 days in the current study further emphasizes the long-term cariostatic potential of high-viscosity GIC. At 28 days, high-viscosity GIC continued to release 2.70 ± 0.51 ppm fluoride, compared to 2.05 ± 0.44 ppm for conventional GIC and 1.60 ± 0.39 ppm for resin-modified GIC. These findings are consistent with Llancari-Alonzo et al., who demonstrated that materials with higher glass content and porosity exhibited greater long-term fluoride diffusion [13].

Cumulative fluoride release up to 28 days was highest for high-viscosity GIC (20.45 ± 2.10 ppm), followed by conventional GIC (17.64 ± 1.86 ppm), with resin-modified GIC showing the lowest cumulative release (14.13 ± 1.54 ppm) and these differences were statistically significant ($p < 0.001$). These observations correspond with findings by Abouelella et al., who reported enhanced cumulative fluoride release from glass hybrid and high-viscosity materials due to their highly reactive glass particles and stronger acid–base reactions [14]. Kelić et al. also emphasized that cumulative fluoride release is strongly influenced by the glass composition and water permeability of the cement matrix [15].

An important aspect of this study was the evaluation of fluoride recharge potential. Following fluoride recharge, all materials exhibited a renewed increase in fluoride release, indicating their ability to act as fluoride reservoirs. High-viscosity GIC again showed the highest post-recharge fluoride release at 24 hours (7.20 ± 0.89 ppm), while resin-modified GIC showed the lowest (4.85 ± 0.69 ppm). This finding is in agreement with Krajangta et al., who demonstrated that high-viscosity GICs possess superior fluoride uptake and re-release capabilities due to their hydrophilic nature and porous microstructure [16]. Done et al. also reported that conventional and hybrid GICs exhibit significantly better fluoride recharge capacity than resin-containing materials [17].

The reduced fluoride release and recharge observed in resin-modified GICs in the present study may be attributed to the presence of resin components, which limit water sorption and ion exchange. Feiz et al. similarly reported lower fluoride release from resin-modified materials when compared to conventional ionomers [18]. Furthermore, systematic reviews by Tokarczuk et al. and Dobrzyński et al. highlighted that material composition, surface characteristics and environmental exposure significantly influence fluoride release behavior, reinforcing the relevance of the present findings [19, 20].

LIMITATIONS

This study was conducted entirely in vitro and therefore the results may not fully replicate the complex oral environment, including factors such as salivary flow, pH fluctuations and mechanical stresses from mastication, which can influence fluoride release and recharge in clinical situations. Additionally, only three types of glass ionomer cements were evaluated and the study did not assess the effect of different surface coatings, fluoride concentrations in recharge agents, or long-term aging of the materials. Future studies incorporating in vivo conditions and a wider range of restorative materials would provide more comprehensive insights into fluoride dynamics in clinical practice.

CONCLUSION

Overall, the results of this study confirm that high-viscosity glass ionomer cement demonstrates superior fluoride release and recharge potential compared to conventional and resin-modified glass ionomer cements. These properties make high-viscosity GIC a favorable restorative option, particularly in patients with high caries risk, where sustained fluoride availability is clinically beneficial.

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Conflicts of interest

There are no conflicts of interest.

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