Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 11, (2022)
https://www.jneonatalsurg.com

"Comparison of Fluoride Recharge and Re-Release among Glass Ionomer, Compomer, and Giomer''

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.Cite this paper as: Dr. Sheikh Muhammad Abdul Quader, Dr. Abdullah Al Mahmud, Mst. Laila Akter Banu, (2022) "Comparison of Fluoride Recharge and Re-Release among Glass Ionomer, Compomer, and Giomer'' *Journal of Neonatal Surgery*, 11,36-44.

ABSTRACT

Background: Fluoride-releasing restorative materials play a crucial role in preventing secondary caries by providing sustained fluoride release and recharge capacity. This study aimed to compare the fluoride release and recharge behavior of glass ionomer, compomer, and giomer restorative materials.

Methods: In this in vitro study, standardized samples of glass ionomer, compomer, and giomer were prepared and immersed in deionized water. Fluoride release was measured on days 1, 3, 6 (before recharge), and days 7, 10, and 13 (after fluoride recharge). Statistical analysis was performed using ANOVA with multiple pairwise comparisons to determine differences among the materials.

Results: Glass ionomer consistently exhibited the highest fluoride release at all time points (8.538 ± 1.282 µg/cm² on day 1; 0.904 ± 0.060 µg/cm² on day 13 after recharge), followed by compomer and giomer. Differences among the materials were statistically significant ($p < 0.001$) at each measurement, with pairwise comparisons confirming superior performance of glass ionomer. Fluoride release decreased over time for all materials, but glass ionomer maintained higher levels even after repeated fluoride recharge. Compomer and giomer showed lower initial release but retained measurable recharge potential.

Conclusion: Glass ionomer demonstrated superior fluoride release and recharge capacity, suggesting enhanced caries-preventive benefits, particularly for high-risk patients or restorations requiring sustained fluoride availability. Compomer and giomer, while less potent, remain viable alternatives when esthetic and mechanical considerations are prioritized

Keywords: *Fluoride release, Fluoride recharge, Glass ionomer, Compomer, Giomer, Restorative materials*

1. INTRODUCTION

Dental caries is a dynamic disease process characterized by the demineralization of the inorganic component and destruction of the organic matrix of tooth structure, ultimately leading to cavitation. Any mechanism that can inhibit acid production, enhance resistance to demineralization, or promote remineralization is therefore of significant clinical importance [1].

The introduction of dental amalgam in the 19th century marked a major advancement in restorative dentistry by allowing durable and cost-effective permanent restorations [2]. However, increasing concerns about mercury toxicity and the poor esthetic appearance of amalgam restorations have led to their decline in popularity [3]. In response to the growing demand for esthetic restorations, resin-based composite materials were developed in the 1960s by Professor Bowen. These materials could be shade-matched to natural teeth, making them highly suitable for anterior restorations [4].

In 1972, Wilson and Kent introduced glass ionomer cement (GIC), a restorative material that quickly gained popularity because of its ability to chemically bond to tooth structure and release fluoride ions continuously [5,6]. Fluoride was later incorporated into pit and fissure sealants to enhance their anti-caries effects [7]. Although the fluoride release from such sealants tends to diminish over time, several studies have demonstrated that these materials can regain their fluoride-releasing capacity after exposure to topical fluoride sources [8,9]. However, only a few studies have comprehensively examined the long-term fluoride recharge and re-release potential of these materials.

The fluoride release pattern of glass ionomer cements and polyacid-modified composite resins (compomers) typically shows an initial burst release during the first few days, followed by a rapid decline to a much lower sustained level [10,11]. This decline may limit their long-term ability to inhibit secondary caries, as the low levels of fluoride released over time may not be sufficient to exert a continuous therapeutic effect [12]. Nevertheless, it has been reported that both glass ionomer cements and compomers can absorb fluoride from external sources and subsequently release it back into the oral environment [9,13]. This fluoride recharge and re-release capability may extend their cariostatic potential, as the recharged fluoride contributes to the total fluoride release over time [14]. Among restorative materials, glass ionomer cements generally demonstrate superior fluoride recharge ability compared to compomers, while resin composites exhibit minimal or negligible recharge capacity [15,16].

Despite their advantages, glass ionomers possess inferior mechanical properties relative to resin composites, limiting their use in high occlusal stress-bearing areas [17]. Moreover, their restricted color range reduces their appeal as highly esthetic restorative materials [18].

The beneficial role of fluoride in caries prevention has been recognized for decades, though its precise mechanism of action remains not fully understood. Fluoride enhances caries resistance through both systemic and topical effects, promoting the formation of fluoroapatite and fluorohydroxyapatite, which are more resistant to acid dissolution [19]. Professional fluoride delivery methods include prophylactic pastes, mouth rinses, and sealants, while unsupervised home-use options involve fluoride-containing dentifrices and rinses [20].

The incorporation of fluoride into restorative materials has therefore drawn considerable attention from researchers and clinicians. These fluoride-releasing dental materials serve as a potential long-term source of low-level fluoride, contributing to the prevention of secondary caries and neutralization of pH fluctuations, especially in patients with a high caries risk [20].

Therefore, the present study was designed to compare the fluoride recharge and re-release behavior among glass ionomer, compomer, and giomer restorative materials.

2. METHODOLOGY & MATERIALS

This experimental study was conducted in the Department of Conservative Dentistry and Endodontics, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, in collaboration with the Analytical Research Division and the Pilot Plant & Process Development Centre of the Bangladesh Council of Scientific and Industrial Research (BCSIR) Laboratories, Dhaka. The study was carried out between January 2007 and December 2008.

This study included a total of seven disc-shaped samples each of glass ionomer, compomer, and giomer restorative materials were prepared to measure fluoride release and recharge.

The following restorative materials were used in this study:

Composite (Quixfil, Caulk/Dentsply, Germany): This material contains a fluoroaluminosilicate glass within a resin matrix, without any glass-ionomer hydrogel component.

Compomer (Dyract Extra, Dentsply DeTrey, Germany): Formulated with strontium-fluorosilicate glass, this material allows for limited glass-ionomer hydrogel formation through a delayed acid–base reaction.

Giomer (Beautifil II, Shofu Inc., Japan): The fluoridated glass filler in this material is fully reacted with acid to form an extensive glass-ionomer hydrogel layer prior to blending with the resin matrix.

Glass Ionomer (Fuji IX, GC America): This product contains calcium-fluoroaluminosilicate glass, in which the fluoridated glass filler is fully reacted with acid to form an extensive glass-ionomer hydrogel layer.

Preparation of Specimens for Fluoride Release and Recharge: A total of seven disc-shaped specimens of each restorative material were prepared to measure fluoride release. The materials were manipulated according to the manufacturers' instructions and placed into cylindrical Teflon molds measuring 10 mm in diameter and 4 mm in height. Each mold was positioned between two microscope glass slides, and the materials were pressed gently to achieve a uniform surface.

For all materials except the self-cured glass ionomer, specimens were light-cured through the glass slides for 40 seconds on both the top and bottom surfaces. After removal from the molds, additional light curing was performed for 40 seconds on each cylindrical side surface to ensure complete polymerization. The self-cured glass ionomer specimens were allowed to set within the mold between the glass slides without light exposure.

A visible light-curing unit (Selector, Taiwan) was used throughout the study to maintain consistent polymerization conditions. Following polymerization, all specimens were removed from the molds and stored in a dry environment at 37°C for 24 hours. Subsequently, each specimen was finished with 800-grit silicon carbide paper under dry conditions to obtain smooth surfaces. The diameter and thickness of each disc were measured precisely, and these dimensions were used to calculate the cross-sectional and total surface areas for standardized fluoride release measurements.

Fluoride Release Procedure: Each test specimen was immersed and stored individually in a plastic container containing 5 ml of distilled/deionized water at 37°C for 24 hours. After each 24-hour interval, every specimen was removed from its container and transferred to a fresh container with 5 ml of new distilled/deionized water. This procedure was repeated daily for six consecutive days to evaluate the pattern of fluoride release over time.

The fluoride concentration in each storage solution was measured using both an Ion-Selective Electrode (ISE) and Ion Chromatography (IC). The amount of fluoride released was expressed as the fluoride concentration per unit surface area of the specimen (µg/cm²), reported in parts per million (ppm) or mg/L.

Fluoride Recharge and Re-Release Procedure: Following the completion of the initial fluoride release measurements, all specimens were stored in 5 ml of distilled/deionized water, which was replaced daily, for a total duration of 13 days. On the 6th day, each specimen was immersed for 1 hour in an aqueous sodium fluoride (NaF) solution containing 250 ppm fluoride to simulate the recharging process. After recharging, specimens were rinsed thoroughly with copious amounts of distilled/deionized water, gently dried, and then transferred to new containers containing 5 ml of fresh distilled/deionized water.

Fluoride release was subsequently measured for:

One day before recharging,

Three days after recharging, and

On the 13th day of storage.

Measurements were again performed using both Ion-Selective Electrode (ISE) and Ion Chromatography (IC). The fluoride release per unit surface area (µg/cm²) in ppm was calculated at each time point. The fluoride recharge capacity of each material was determined by the difference in fluoride release during the 24-hour periods before and after recharging.

Study Parameters: The main parameters evaluated in this study were fluoride release, fluoride recharge Fluoride release was measured over an initial 6-day period, followed by a recharging phase using a 250 ppm fluoride solution. The re-release of fluoride was then measured on the 7th day and again on the 13th day. The amount of fluoride released per unit surface area of each specimen (µg/cm², expressed in ppm) was determined at each time point using Ion Chromatography (IC). The fluoride recharge capacity was indicated by the difference in fluoride release measured during the 24-hour periods before and after recharging.

Data Collection: All data obtained from the experimental procedures were carefully recorded and organized for statistical evaluation. The collected data were then compiled and prepared for subsequent statistical analysis to determine the significance of observed differences among the tested materials.

Statistical Analysis: Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS), version 11.5. Data were expressed as mean ± standard deviation (SD). The Analysis of Variance (ANOVA) test was employed to compare the mean values among the different material groups. A p-value of less than 0.05 ($p < 0.05$) was considered statistically significant. When significant differences were identified, Bonferroni multiple comparison tests were applied to determine pairwise differences between groups.

3. RESULTS

Table 1: Fluoride release by giomer, compomer and glass ionomer on day 1 (before recharge)

Material	**n**	**Range**	**Mean±SD**	**P value**
Giomer	7	1.080-1.413	1.288±0.126	<0.001
Compomer	7	1.997-2.439	2.111±0.162	
Glass ionomer	7	6.460-10.562	8.538±1.282	
Comparison				
Giomer vs Compomer				>0.10
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 1 shows that the highest mean fluoride release was observed in the glass ionomer group (8.538 ± 1.282), followed by the compomer (2.111 ± 0.162) and the giomer (1.288 ± 0.126) on the first day before fluoride recharge. The differences among the groups were statistically significant ($p < 0.001$). Multiple comparison analysis revealed that the glass ionomer released significantly more fluoride than both the giomer and compomer ($p < 0.001$), whereas the difference between giomer and compomer was not statistically significant ($p > 0.10$).

Table 2: Fluoride release bey giomer, compomer and glass ionomer on day 3 (before recharge)

Material	**n**	**Range**	**Mean±SD**	**P-value**
Giomer	7	0.266-0.383	0.315±0.052	<0.001
Compomer	7	0.466-0.577	0.517±0.046	
Glass ionomer	7	1.698-2.480	1.988±0.246	
Comparison				
Giomer vs Compomer				>0.05
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 2 shows the mean fluoride release (µg/cm²) of giomer, compomer, and glass ionomer restorative materials on the third day before fluoride recharge. Among the three materials, glass ionomer demonstrated the highest fluoride release (1.988 ± 0.246), followed by compomer (0.517 ± 0.046) and giomer (0.315 ± 0.052). The difference in fluoride release among the materials was statistically significant ($p < 0.001$). Multiple comparison analysis indicated that the glass ionomer released significantly more fluoride than both giomer and compomer ($p < 0.001$), while the difference between giomer and compomer was not statistically significant ($p > 0.05$).

Table 3: Fluoride release by giomer, compomer and glass ionomer on day 6 (before recharge)

Material	**n**	**Range**	**Mean±SD**	**P value**
Giomer	7	0.164-0.373	0.246±0.064	<0.001
Compomer		0.419-0.522	0.473±0.037	
Glass ionomer		0.950-1.174	1.040±0.073	
Comparison				
Giomer vs Compomer				<0.001
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 3 shows that the glass ionomer exhibited the highest mean fluoride release (1.040 ± 0.073), followed by the compomer (0.473 ± 0.037) and the giomer (0.246 ± 0.064) on the sixth day before fluoride recharge. The differences in fluoride release among the three materials were statistically significant ($p < 0.001$). Multiple comparison analysis revealed that all pairwise comparisons—giomer vs. compomer, giomer vs. glass ionomer, and compomer vs. glass ionomer—showed significant differences ($p < 0.001$).

Table 4: Fluoride release by giomer, compomer and glass ionomer on day 7 (after recharge)

Material	**n**	**Range**	**Mean±SD**	**P-value**

Giomer	7	0.190-0.4180	0.313±0.073	<0.001
Compomer	7	0.434-0.5810	0.497±0.044	
Glass ionomer	7	1.279-1.508	1.371±0.082	
Comparison				
Giomer vs Compomer				<0.001
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 4 shows that the glass ionomer exhibited the highest mean fluoride release (1.371 ± 0.082), followed by the compomer (0.497 ± 0.044) and the giomer (0.313 ± 0.073) on the 7th day following fluoride recharge. The differences in fluoride release among the three materials were statistically significant ($p < 0.001$). Multiple comparison analysis revealed significant differences between giomer and compomer ($p < 0.001$), giomer and glass ionomer ($p < 0.001$), and compomer and glass ionomer ($p < 0.001$).

Table 5: Fluoride release by giomer, compomer and glass ionomer on day 10 (after recharge)

Material	**n**	**Range**	**Mean±SD**	**P-value**
Giomer	7	0.119-0.227	0.173±0.037	<0.001
Compomer	7	0.329-0.461	0.399±0.042	
Glass ionomer	7	0.803-1.504	0.946±0.079	
Comparison				
Giomer vs Compomer				<0.001
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 5 presents the fluoride release (µg/cm²) from giomer, compomer, and glass ionomer restorative materials on the 10th day after fluoride recharge. The glass ionomer exhibited the highest mean fluoride release (0.946 ± 0.079), followed by the compomer (0.399 ± 0.042) and the giomer (0.173 ± 0.037). The overall differences among the three materials were statistically significant ($p < 0.001$). Pairwise comparisons showed significant differences between giomer and compomer ($p < 0.001$), giomer and glass ionomer ($p < 0.001$), and compomer and glass ionomer ($p < 0.001$).

Table 6: Fluoride release by giomer, compomer and glass ionomer on day 13 (after recharge)

Material	**n**	**Range**	**Mean±SD**	**P value**
Giomer	7	0.089-0.193	0.147±0.032	<0.001
Compomer	7	0.353-0.426	0.393±0.026	
Glass ionomer	7	0.826-0.988	0.904±0.060	
Comparison				
Giomer vs Compomer				<0.001
Giomer vs Glass ionomer				<0.001
Compomer vs Glass ionomer				<0.001

Table 6 demonstrates the fluoride release (µg/cm²) from giomer, compomer, and glass ionomer restorative materials on the

13th day following fluoride recharge. Among the tested materials, the glass ionomer exhibited the highest mean fluoride release (0.904 ± 0.060), followed by the compomer (0.393 ± 0.026) and the giomer (0.147 ± 0.032). The differences in fluoride release among all three materials were statistically significant ($p < 0.001$). Pairwise comparisons indicated significant differences between giomer and compomer ($p < 0.001$), giomer and glass ionomer ($p < 0.001$), and compomer and glass ionomer ($p < 0.001$).

4. DISCUSSION

The present study evaluated the fluoride release and recharge capacity of glass ionomer, compomer, and giomer restorative materials over a 13-day period. On the first day, glass ionomer exhibited a markedly higher fluoride release compared to compomer and giomer, demonstrating its rapid initial fluoride liberation. By days 3 and 6, fluoride release from all materials declined; however, glass ionomer consistently maintained significantly higher levels, compomer showed intermediate values, and giomer the lowest. Following fluoride recharge on day 6, all materials exhibited an increase in fluoride release, with glass ionomer showing the greatest enhancement on day 7, indicating superior recharge capacity. By days 10 and 13, fluoride release gradually declined in all groups, yet glass ionomer continued to release the highest amounts, followed by compomer and giomer. These findings suggest that while all three materials are capable of fluoride recharge, glass ionomer maintains a more sustained release, which may contribute to long-term caries prevention. Compomer and giomer, despite lower release levels, still retain measurable fluoride recharge potential, which may be beneficial in esthetically demanding restorations.

Several studies have reported similar trends, although results vary considerably due to differences in methodology, specimen size, storage media, frequency of media change, and measurement techniques [1, 21]. The fluoride content and release from restorative materials should be sufficiently high to inhibit bacterial viability and promote remineralization of enamel and dentin, without compromising material integrity. The initial high fluoride release observed on the first day is attributed to superficial rinsing, whereas subsequent release occurs via diffusion through the cement pores and microfractures [1, 21]. This dual-phase release pattern, an initial surface “burst” followed by slower bulk diffusion has been documented in previous studies [22]. Unlike conventional and resin-modified glass ionomers, giomers and polyacid-modified composites exhibit no pronounced initial burst; however, their fluoride release remains relatively constant over time. Despite the absence of a burst effect, cumulative fluoride release from giomer was higher than that of compomer [23]. Comparatively, the initial fluoride release of dental restoratives follows the descending order: conventional GIC, RMGIC, giomer, and compomer, consistent with findings from Vermeersch, Leloup, Vreven, and Karabulut et al. [10,24]. This hierarchy can be explained by the extent to which a glass ionomer matrix layer surrounds the glass filler in the set material.

Giomers employ pre-reacted glass ionomer technology to form a stable GIC phase within the restoration. The more extensive acid-base reaction and hydrogel layer of glass fillers are responsible for higher fluoride release in giomers compared to compomers [25]. Compomers, containing cycloaliphatic dicarboxylic acid dimethacrylate monomers and reactive glass fillers, initially undergo light polymerization, take up water over time, and allow the carboxylic groups of the acidic monomer to participate in acid-base reactions with metal ions in the glass filler [26]. Fluoride release occurs via water uptake and subsequent dissolution of glass filler particles or ionic reactions on the glass particle surface [25]. Glass ionomer formulations can be recharged and release fluoride gradually after exposure to topical fluoride sources such as toothpaste and mouth rinses [26,27].

Takahashi et al. demonstrated that fluoride release by glass ionomer materials increases with higher fluoride exposure concentrations [22]. Similarly, Freedman and Diefendefer concluded that home-care fluoride exposure provides measurable fluoride uptake and release, particularly in resin-modified glass ionomers [28]. Xu et al. (2003) observed that glass ionomers exhibit a high initial fluoride release (~40 $\mu g/cm^2/day$ or 8 ppm), which declines rapidly after the first three days but continues at a lower, sustained level over time, with excellent fluoride recharge capability. In contrast, compomers initially release lower fluoride levels (<10 $\mu g/cm^2/day$ or 2 ppm) and sustain this release at similar levels over time [29]. Bell et al. (1999) and Attar & Turgut (2003) reported higher first-day fluoride release from glass ionomer (~15 ppm), while Attar & Onen (2002) found first-day compomer release of 1–2.4 ppm, consistent with our findings [17,30,31].

Itota et al. reported that giomers release fluoride in a more controlled manner than traditional glass ionomers, while composites lacking fluoride-containing fillers exhibited negligible release [32]. Finally, Naoum et al. (2011) confirmed that conventional GICs possess high fluoride recharge capability [33]. Overall, these previous studies support the trends observed in the present investigation, emphasizing the superior fluoride release and recharge potential of glass ionomer compared to compomer and giomer materials.

5. LIMITATIONS OF THE STUDY

This study has several limitations. It was conducted in vitro, which may affect fluoride release and recharge in vivo. The sample size was small, and only one brand per restorative material type was tested, limiting generalizability. Additionally, the study assessed short-term fluoride release over 13 days, without evaluating long-term kinetics or clinical outcomes.

6. CONCLUSION AND RECOMMENDATIONS

In the present study, glass ionomer restorative materials showed the highest fluoride release and recharge capacity, followed by compomer and giomer. Although fluoride release decreased over time for all materials, glass ionomer consistently maintained superior levels, even after repeated fluoride recharge. These results indicate that glass ionomer may provide enhanced caries-preventive benefits, particularly for high-risk patients or restorations requiring sustained fluoride release. Compomer and giomer, despite lower fluoride release, still demonstrated measurable recharge potential and can be considered suitable alternatives when esthetics and mechanical properties are priorities.

Future studies should evaluate long-term fluoride kinetics and clinical performance to confirm these findings.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: This study was ethically approved

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