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Research Article

Influence of GIC Type, Fluoride Recharge Agent and Storage Time on Fluoride Release from Restorative Materials

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ABSTRACT

Background: Glass ionomer cements (GICs) are frequently used restorative materials because of their capacity to release fluoride, which aids in caries prevention. Fluoride release varies with the kind of GIC, exposure to fluoride recharging agents, and time; little clinical data on their invitro behavior is available. **Objective**: To assess the impact of GIC type and a fluoride recharge agent on fluoride release from restorative materials in a patient-based study. **Materials and Methods**: 25 patients (18–60 years) needing Class I or Class V restorations were surveyed cross sectionally. Patients were randomly divided into three groups based on GIC kind: ordinary GIC (n = 8), resin-modified GIC (n = 8), and high-viscosity GIC (n = 9). Within each group, some patients received no recharge while others received topical fluoride varnish (recharge). 24 hours after the placement of the restorations, unstimulated whole saliva samples were taken. With TISAB buffer, an ion-selective electrode was used to measure fluoride concentration; restoration performance was rated using USPHS criteria. **Results**: At 24 hours, all GIC types showed measurable fluoride release; resin-modified and high-viscosity GICs released more fluoride than ordinary GIC. Increased fluoride in saliva along with no group differences, clinical evaluation showed suitable instant restoration integrity in all patients. **Conclusion**: Within the limits of this cross-sectional investigation, both the type of GIC and fluoride recharge agent use significantly impacted short-term fluoride release. Greater fluoride levels resulted from high-viscosity GICs and resin-modified materials used with fluoride varnish; therefore, their relevance in preventing caries was supported.

Keywords: Glass ionomer cement, fluoride release, fluoride varnish, restorative materials, cross-sectional clinical study

INTRODUCTION

Fluoride is regarded as base for preventing dental decay. It has antibacterial activity against cariogenic bacteria, promotes remineralization, and stops demineralization. Besides their adhesive properties, their biocompatibility, and their fluoride-releasing property, glass ionomer cements (GICs) have an edge in the context of restorative dentistry. The rate of release and the amount of time of the fluoride release varies with numerous factors including the material, the environment, and the compounds that recharge the fluoride. These aspects may be used to choose repair materials and increase the preventive activities of a clinical environment. GICs release fluoride in accordance with their chemical composition as well as microstructure. Conventional GICs are likely to be more viable to release fluoride than resin-modified GICs (RMGICs) that involve resin materials and respond to an acid-base condition but slow release. RMGICs can be used to better recharge the fluoride (Mikami et al., 2025). On the contrary, high-viscosity, as well as glass hybrid GICs are prepared to possess high mechanical properties. It is found that they can hold more fluoride longer and in greater quantities than normal GICs. Therefore, the type of GIC is also a significant factor in determining the trend of fluoride release in the dentistry profession (Mansour et al., 2021).

Charges for fluoride consist of sodium fluoride gel, fluoride varnish, or acidulated phosphate fluoride (APF) gel. After their first burst of activity has subsided, research reveals RMGICs to be superior in fluoride rechargeability compared to conventional GICs (Khalil et al., 2023); these substances may restore the fluoride-releasing ability of dental repair materials. particularly following topical fluoride therapy (Shah et al., 2025). The type, dose, and duration of fluoride exposure have all been shown to influence charging efficiency; therefore, maximizing clinical outcomes depends on this crucial factor.

Another important consideration is the time between restoration insertion. Usually following a biphasic pattern, fluoride release consists of an initial great release within the first 24–72 hours, followed by a continuous fall over the next weeks and months (Morales-Valenzuela et al., 2022). Research reveals that while short-term data provide more insight on the sustainable release possibility of a material, longer storage times give more information and better represent the direct caries-preventive effect. Therefore, assessing fluoride release across several time spans offers a full knowledge of material behavior in real clinical settings (Nishanthine et al., 2023).

Though not the main concern of the current research, other factors includes powder-liquid ratio, temperature, storage medium (water, artificial saliva, or acidic solutions), and present Surface coatings have also been found to affect fluoride release and recharge behavior. Interpreting findings should take into account these as possible confounding variables (Malik et al.,2023).

Enhancements to GIC formulas to enhance both fluoride discharge and rechargeability have recently been investigated in several studies. For instance, assessed GICs strengthened with titanium dioxide nanoparticles and found that the altered cements exhibited more and more persistent fluoride better recharge and release than unaltered GICs without any cytotoxic effects (Morales-Valenzuela et al., 2022). Another study matched recently developed glass ionomer materials (Equia Forte HT and Micron Bioactive) with conventional Type II GIC and found Equia Forte HT the greatest fluoride emission over 14 days (Dcruz,2024). A 2021 study evaluated zirconia-reinforced, resin-modified, and traditional GICs as well; zirconia-reinforced GIC emitted more fluoride and demonstrated better rechargeable fluoride ion release, following uses of an acidulated phosphate fluoride gel (Surabhilakshan, 2021).

Other studies have investigated altering GICs by means of natural or bioactive ingredients. For instance, one study found that chitosan nanoparticles added to GIC dramatically increased fluoride release relative to typical and resin-modified GICs (Nishanthine et al., 2022–2023). Malik et al. (2023) also looked at glass ionomers cements including fluoroapatite (FA) and hydroxyapatite (HA), demonstrating that the FA-added GICs released far more fluoride then HA-addedversions had less effect, controls These results point to the base material as well as the additions or reinforcements greatly affecting the profiles of fluoride release.

Despite the abundance of in vitro data, there remains relatively less evidence from in vivo or patient-based studies that evaluate fluoride release under clinical conditions. Real-world exposure to fluoride (e.g., through toothpaste, varnish), oral hygiene, diet, and salivary flow can change the amount of fluoride released or recharged from restorations. The fact that the first 24 hours of release is required is particularly important in the short run to prevent premature demineralization or secondary cavities on the edges of the restorations.
Against this background, one has to statistically examine how several types of GICs react concerning fluoride release and how effectively fluoride charging is accomplished. Within a brief storage time, agents can augment this influence. This will assist practitioners in choosing preventative therapies and restorative materials to maximize caries prevention and restoration life span in actual patients.

METHODOLOGY

This research was conducted as a patient-based, cross-sectional clinical study meant to assess the effect of glass ionomer cement (GIC) type, fluoride recharge using a topical storage time and agent on the release of fluoride from restorative materials as well as on their immediate clinical performance. As in vivo circumstances provide more correct data on the fluoride-releasing behavior of materials, a clinical design was chosen instead of a purely laboratory method, under patient-specific factors, saliva, and oral pH variations. Over a three-month period, the investigation was carried out in the Department of Operative Dentistry. Every patient was given a thorough description of the study aim and methodology. Written informed permission was acquired.
The patients at the outpatient dental clinics who needed restorative care for carious lesions made up the study population. Adults aged between 18 and 60 years with Class I or Class V cavities were considered eligible, provided they were systemically healthy and had not preceded six months of received professional fluoride treatment; patients with xerostomia, salivary gland problems, or systemic diseases and those on long-term medicines. Individuals with extreme caries or needing numerous extensive fillings were likewise rejected as this might confuse the fluoride release measurements; influence salivary flow were excluded. Ethical considerations led to the exclusion of pregnant and lactating women.
25 patients were recruited by way of basic random sampling. Depending on the type of restorative material used, they were put in one of three groups: conventional glass ionomer cement (n = 8), resin-modified glass high-viscosity glass ionomer cement (n = 9) and ionomer cement (n = 8). Every group was then split into two groups. One group of patients received a topical fluoride recharge right after repair placement using a 5% sodium fluoride varnish; the other group did not get any extra fluoride therapy. This distribution let comparison between several GIC types as well as between recharge and non-recharge situations.
The researcher carried out all surgical operations under standardized clinical settings. To avoid overheating and damage to the tooth structure, cavity preparations were done with sterile diamond burs under water coolant. According to the manufacturer's directions, the assigned restorative substance was manipulated and applied. Fluoride varnish was applied straight onto the restored tooth surface in the recharge subgroups, replicating the preventive dental care sometimes administered in clinical practice.
Data gathering included clinical as well as chemical testing. Each patient's baseline and then 24 hours following restoration placement unstimulated whole saliva was gathered. Patients were advised to refrain from eating, drinking, or performing oral hygiene operations for at least one hour before sample gathering to reduce contamination. Saliva samples were kept in sterile polyethylene tubes at 4 degrees Celsius till lab examination. A fluoride ion-selective electrode was used to determine fluoride concentration; a total ionic strength correction buffer (TISAB) stabilized ionic activity and prevented interference from other ions. Apart from laboratory analysis, 24 hours after installation each restoration was assessed clinically according to the United States Public Health Service (USPHS) guidelines. This assessment offered information on the short-term clinical performance of the restorations by evaluating marginal adaptation, surface roughness, color match, and the presence or absence of secondary caries.
The primary outcome measure of the research was the fluoride concentration expelled into saliva after 24 hours; the secondary outcome measure was the as assessed medically, immediate performance of the repairs. The data was entered and analysed via

SPSS software (version XX) with the help of SPSS software. The percentages, means and the standard deviations were calculated by use of descriptive statistics. The difference in the fluoride release between the recharge and non-recharge groups was tested in the independent samples t-tests; in this case, one-way For this paper, the variance analysis (ANOVA) followed by the Tukey post-hoc test to compare the two-way comparisons were applied. Otherwise, not significant below p-value of 0.05.

RESULTS

Table 1. Demographic Characteristics of Patients (n = 25)

Variable	n (%)
Age (years)	Mean ± SD = 34.6 ± 9.2
Age range	18–60
Gender	Male: 12 (48%) Female: 13 (52%)
Tooth type restored	Anterior: 9 (36%) Posterior: 16 (64%)

Table 2. Distribution of Patients by GIC Type and Recharge Status

Group	No Recharge (n)	Fluoride Varnish Recharge (n)	Total
Conventional GIC	4	4	8
Resin-Modified GIC	4	4	8
High-Viscosity GIC	4	5	9

Table 3. Mean Salivary Fluoride Concentration (ppm) After 24 Hours

GIC Type	No Recharge (Mean ± SD)	Recharge (Mean ± SD)	p-value
Conventional GIC (n=8)	0.32 ± 0.05	0.55 ± 0.07	<0.01
Resin-Modified GIC (n=8)	0.45 ± 0.06	0.78 ± 0.08	<0.01
High-Viscosity GIC (n=9)	0.48 ± 0.05	0.81 ± 0.09	<0.01
Overall	0.42 ± 0.08	0.72 ± 0.12	<0.01

Table 4. Comparison of Fluoride Release Across GIC Types (ANOVA Test)

Comparison	F-value	p-value
Conventional vs RMGIC	7.21	<0.01
Conventional vs HVGIC	8.14	<0.01
RMGIC vs HVGIC	1.02	0.31
Overall (3 groups)	9.44	<0.001

Table 5. USPHS Clinical Evaluation of Restorations at 24 Hours

Criteria	Alpha (Excellent)	Bravo(Acceptable)	Charlie(Unacceptable)
Marginal adaptation	24 (96%)	1 (4%)	0
Surface roughness	23 (92%)	2 (8%)	0
Color match	22 (88%)	3 (12%)	0
Secondary caries	25 (100%)	0	0

DISCUSSION

The importance of the current clinical research study was to investigate what effect the different types of glass ionomer cements (GICs), fluoride restoring treatments and storage period has on fluoride release. The study involved patients who had to have class I and class V restorations. The findings showed that the volume of fluoride to be released highly relied on the use of fluoride varnish and the material used. The temporal transformations were of the usual type that was typical in earlier research.

GICs with high viscosity and resin-modified GICs were reported to release more fluoride compared to the conventional GICs. It is validated by Mansour et al. (2021), who developed the position that conventional mixes were inferior in terms of fluoride discharge and rechargeability compared to resin-modified and zirconia-reinforced GICs. Similarly, Mikami et al. (2025) have affirmed that the fluoride release pattern of RMGICs was more stable, which is, presumably, attributable to its hybrid resin-glass structure over time that increases the retention and release of fluoride ions. These results indicate the importance of the material structure in regulating the clinical liberation of fluoride.

The use of a refill of a fluoride varnish demonstrated a significant rise in salivary fluoride level in each group. This concurs with the results of Khalil et al. (2023) who stated that local fluoride interventions in particular varnish and APF gel are used to restore GICs and enhance their cariostatic effect according to the results of Shah et al. (2025). The end of this paper could be explained by the fact that resin-modified GICs possess a superior recharge of the traditional types. These findings lend credence to the therapeutic benefit of combining GIC restorations with preventive fluoride treatments for maximum caries control.

Significantly fluoride release was found during the first 24 hours in the current study, hence supporting the first burst effect idea on storage time. Early emphasis is on how important this is for preventing demineralization and providing fast defense against secondary caries, as in fluoride release, et al. (2022).

Studies such Nishanthine et al. (2023) and Malik et al. (2023) have shown that sustained release continues at lower levels over longer periods. Suggesting for weeks to months that observations made over a short period, say 24 hours, offer just a limited perspective of the long-term performance. However, in clinical practice, this initial fluoride availability may be particularly important in the high-risk period following restoration placement.

Interestingly, all restorations in this study were found to have acceptable clinical integrity within 24 hours regardless of material type, indicating that fluoride release did not compromise the mechanical stability of the restorations. This aligns with recent findings by Morales-Valenzuela et al. (2022), who reported that modifications enhancing fluoride release (e.g., nanoparticle reinforcement) did not negatively affect biocompatibility or initial performance.

Taken together, the current results offer clinical proof that short-term fluoride release is mostly impacted by the type of GIC and the presence of a fluoride refill agent. Resin-modified and high-viscosity GICs, when combined with fluoride varnish, showed the highest saliva fluoride levels, hence supporting their function in caries prevention techniques. The findings' generalizability, however, is limited by the limited sample size and brief follow-up period. Better defining the long-term fluoride release and recharge behavior of restorative materials requires future research on larger populations, extended observation periods, and varied clinical conditions.

LIMITATIONS

This research is acknowledged to have some shortcomings. The sample size was rather modest (25 patients), which may restrict the statistical power and generalizability of the results first. These results have to be confirmed by more extensive multicenter studies. Second, the long-term behavior of restorative materials is not totally reflected by the assessment of fluoride release at just one time point (24 hours). Because fluoride release usually follows a biphasic pattern with both immediate and sustained phases, (Mikami et al., 2025) longer follow-up intervals are required to record clinically significant release patterns. Thirdly, although clinically important, the measurement of fluoride levels in saliva only may not totally reflect the fluoride emitted at the tooth-restoration interface where Its cariostatic effect is most important. Moreover, patient-related characteristics like salivary flow rate, dietary fluoride consumption, and oral cleanliness habits were not monitored and could have affected the outcomes. Finally, just one kind of fluoride recharge agent—fluoride varnish was assessed; testing many doses and formulations could give a more thorough grasp.

FUTURE SUGGESTIONS

Future research should investigate several possibilities. External validity of results will be enhanced by bigger sample sizes and diverse populations. One-day, one-week, one-month, three-month, and further longitudinal designs with several follow-up times are recommended to track both short- and long-term fluoride release and recharging trends.Determining the most efficient one would be aided by a review of several fluoride recharge treatments including acidulated phosphate fluoride (APF) gel, sodium fluoride gel, and fluoridated mouth washes. Furthermore examining surface and structural variations in restorative materials following fluoride, preventative strategy is combined with GIC fillings (Shah et al., 2023; Khalil et al., 2023). 2025). One might replenish with microanalytical methods like scanning electron microscopy (SEM) or energy-dispersive spectroscopy (EDS). Patient characteristics including diet, saliva characteristics, and caries risk all of which could affect fluoride dynamics should also be considered in future clinical studies along side GICs. Furthermore insight on new possibilities will come from restorative materials, such as ionomers and bioactive compounds.

CONCLUSION

It follows within the constraints of this cross-sectional clinical investigation that the type of GIC and fluoride application both have effects. Charging Agent has a major influence on fluoride release in the near future. Higher fluoride release than traditional GIC was shown by high-viscosity GICs and resin-modified GICs; fluoride varnish application significantly increased saliva fluoride. These results stress the need of preventative strategies and material selection for optimizing the cariostatic effects of restorative materials. More validation of these results and direct evidence-based restorational effort calls for long-term clinical trials.

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