



COMPARATIVE EVALUATION OF FLUORIDE RELEASE FROM A COMPOMER, A GIOMER AND A CONVENTIONAL GIC

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ABSTRACT

Purpose: The aim of the study was to measure and compare the release of fluoride ions from three bioactive restorative materials used for restorations in primary dentition - conventional GIC Fuji IX GP Extra, compomer Dyract and giomer Beautifil II.

Materials and methods: 20 samples with a diameter of 6 mm and a thickness of 2 mm were made from the tested materials. At the beginning of the test, all samples were immersed in 5 ml of deionized water and placed in an incubator for 24 hours at $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$. After 24 hours, the concentration of fluoride ions in the medium was measured with an ion-selective electrode for fluorides connected to an ion meter. During this time, the removed cylindrical samples were washed with fresh deionized water, dried, and transferred to new vials with 5 ml of fresh deionized water. The described procedure was repeated every day for a week and then on the 14th, 21st and 28th days.

Results: GIC outperformed compomer and giomer in terms of fluoride ions release for all time intervals with a statistically significant difference. The difference between compomer and giomer was not reliable, but compomer demonstrated higher values for all time intervals.

Conclusion: All studied materials released fluoride ions during the entire experimental period, with the highest concentrations being recorded on the first day of the study. GIC outperformed compomer and giomer many times in terms of fluoride release for all time intervals.

Keywords: compomer, giomer, conventional GIC, fluoride release, primary dentition,

INTRODUCTION

One of the modern principles in dentistry is that materials do not simply restore the tooth but also help in the prevention of caries by reducing caries risk [1]. The incorporation of fluoride in their composition is among the most effective methods to achieve this task [2].

Fluorides are incorporated in the structure of conventional GICs, resin-modified GICs, compomers and gomers [3, 4].

The release of fluoride ions is a complex process, and their amount can be affected by several factors such as the media in which the samples are stored, temperature, the powder liquid ratio of the material, the composition of the matrix and the fillers, formation of biofilm and pellicle [5,6].

Glass ionomer cements contain weak polymeric acids, fluoroaminosilicate glass and water [7]. According to many scientific studies, GICs are the best fluoride releasing restorative materials[8]. Many investigators have demonstrated the ability of GICs to increase the fluoride content in enamel and dentine adjacent to restorations and, thus, to increase their resistance to acid attacks[9]. It has also been proven that these materials release fluoride ions throughout the life of the restorations [10].

The listed advantages of these materials, however, bring with them a number of disadvantages, such as low resistance to abrasion, low mechanical strength and bad esthetics[9]. Because of their low mechanical strength, these materials are not clinically applicable stress bearing areas [10]. In order to overcome the above listed disadvantages of GICs, hybrid esthetic bioactive restorative materials have been developed, such as resin-modified GICs, compomers and gomers [11].

The aim of this study was to evaluate and compare the release of fluoride ions from three restorative materials used in primary dentition.

MATERIALS AND METHODS

The object of the study was three restorative materials- Fuji IX GP extra, Dyract and Beautifil II. Twenty identical samples were made from each material, divided into 3 groups (table 1).

Table 1. Grouping of the experimental samples according to the type of restorative material.

Group	Number of samples	Restorative material-composition	Manufacturer
Group 1	20	Conventional GIC - Fuji IX GP Polyacrylic acid, aluminosilicate glass, distilled water.	GC
Group 2	20	Compomer - Dyract XP Filler: Str-al-na-F-p-silicateglass, Strontium fluoride Matrix: UDMA, TCB, resin, methacrylate	Dentsply Sirona
Group 3	20	Giomer – Beautifil II S-PRG, aluminosilicateglass, Bis-GMA, TEGDMA, catalyst	Tokuyama Dental

Preparation of the specimen

A stainless-steel matrix (6mm x 2mm) coated with Miller strips was used to prepare these standardized samples. The materials were prepared according to the manufacturer's instructions and packed into the moulds. The conventional glass-ionomer cement was allowed to be set at room temperature for 15 minutes. The compomer and giomer were polymerized through the glass slide using a LED wireless curing unit. After setting, the specimens were cleaned, and each of them was polished sequentially with coarse, medium, and fine aluminum oxide discs to remove the unpolymerized and oxygen-inhibited surface layer - it can increase the level of fluoride release from the material. Then specimens of each group were immersed in 5 ml of deionized water in plastic bottles and stored in the incubator at 37°C for 24 hours.

After 24 hours, the containers were thoroughly shaken, and then the samples were removed, dried, and returned into a new vial containing 5 ml of deionized water. Meanwhile, the concentration of fluoride ions in the storage media was measured with an ion-selective electrode for fluoride ions connected to an ion-meter (fig. 1). The described procedure was repeated every day for one week, and then on the 14th, 21st and 28th day. This allowed not only measuring of concentration of released fluoride ions but also measuring the change in concentration over time.

Statistical analysis was performed using Analysis of Variance (ANOVA) for multiple groups and Tukeys multiple post hoc procedure (T HSD) for pair wise comparison of two groups.

The concentration of fluoride was determined by ISE meter (Mettler Toledo SevenMulti™) and PerfectION™ combined fluoride ion selective electrode (fig. 1). All samples were analyzed after adding 5.0 mL total ionic strength adjustment buffer (TISAB) in order to avoid matrix interferences providing a constant background ionic strength and adjustment of pH. TISAB was prepared by mixing 57 mL glacial acetic acid and 500 mL distilled water, followed by the dissolving 58 g sodium chloride and 6 g disodium citrate dihydrate. In order to achieve pH 5.0 – 5.5, 180 mL

Fig. 1. Ion-selective electrode Mettler Toledo, with which the study was conducted.



NaOH (5 mol/L) was added. After cooling the solution to room temperature, it was poured into a 1 L volumetric flask and diluted to the mark with distilled water.

Fluoride standard solution (1000 mg/L) was used for preparing the calibration standards by appropriate dilutions. The limit of quantitation (LOQ, 10σ criteria) was calculated after the measurement of the blank sample and defined to be 0.03 ppm.

RESULTS

The fluoride release values of the tested materials are given in Table 2.

Table 2. Inter-group analysis for fluoride release at different time intervals.

	Fuji IX GP		Dyract		Beautifil II		P value	Post-hoc test (Tukey Kramer)
	Mean (ppm)	SD	Mean (ppm)	SD	Mean (ppm)	SD		
Day 1	20,88	2,42	0,6	0,06	0,46	0,08	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 2	5,43	1,2	0,54	0,1	0,2	0,03	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 3	3,88	1,06	0,39	0,05	0,14	0,02	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 4	2,8	0,82	0,29	0,06	0,1	0,02	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 5	2,27	0,64	0,2	0,03	0,08	0,01	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 6	1,71	0,42	0,16	0,02	0,07	0	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 7	1,63	0,36	0,15	0,02	0,06	0,01	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 14	1,3	0,35	0,1	0,02	0,04	0,002	<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 21	0,98	0,26	0,08	0,02	<0.03		<0.05	Fuji GP Extra >Dyract XP, Beautifil II
Day 28	0,70	0,18	0,07	0,02	<0.03		<0.05	Fuji GP Extra >Dyract XP, Beautifil II

Analysis of the results showed that all three materials released fluoride ions throughout the study period. Their amount over time is different between the three studied materials.

The maximum cumulative fluoride release was related to the conventional GIC, and the difference is statistically significant ($p < 0.05$, table 2). The compomer released more fluoride ions than the giomer for all time intervals, but the difference was not statistically significant (table 2).

On comparison of the 1st- 7th, 14th, 21st and 28th

day, the fluoride release from all the materials was highest on the 1st day (table 2). On intragroup analysis, the release was seen to be decreasing across all the time intervals (table 2, fig. 2). For the conventional GIC, there was a sharp decline in fluoride release after the 1st day, after that, the release decreased gradually till the 28th day (fig. 3). The pattern of release was analogical for the giomer, but the fluoride ions concentration after the 7th day falls below 0.03 ppm (fig. 5). As for the compomer, the release decreased gradually for all time intervals (fig. 4).

Fig. 2. Comparison of the studied materials regarding the release of fluoride ions during the different time intervals.

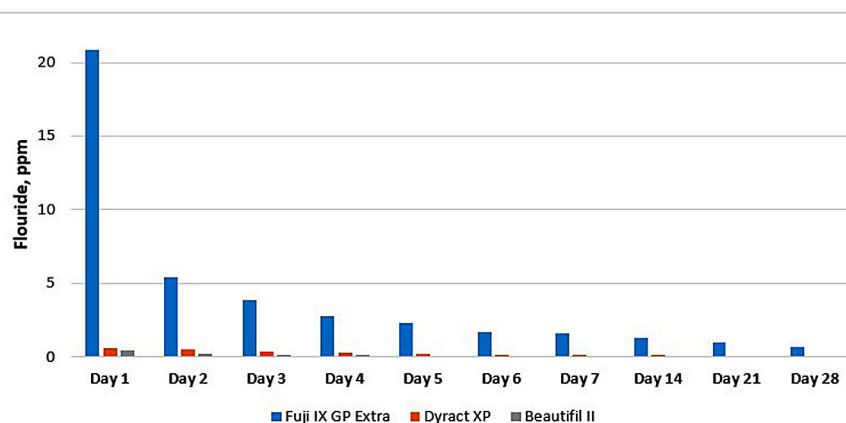


Fig. 3. Fluoride release pattern of Fuji IX GP Extra

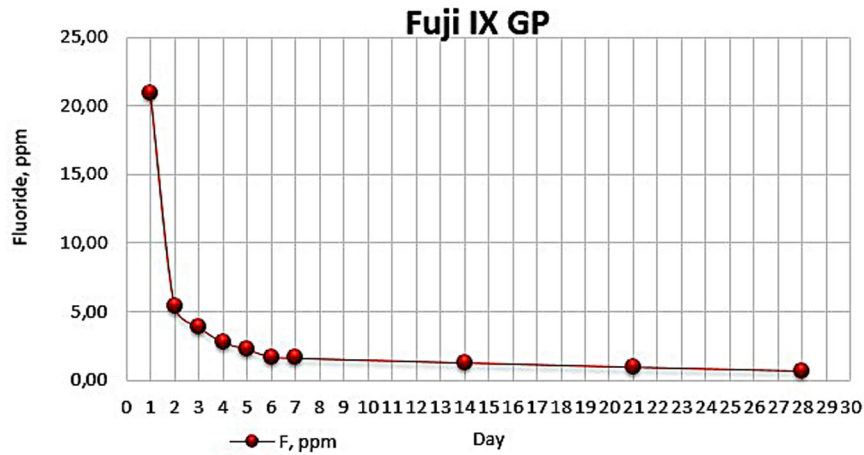


Fig. 4. Fluoride release pattern of Dyract XP

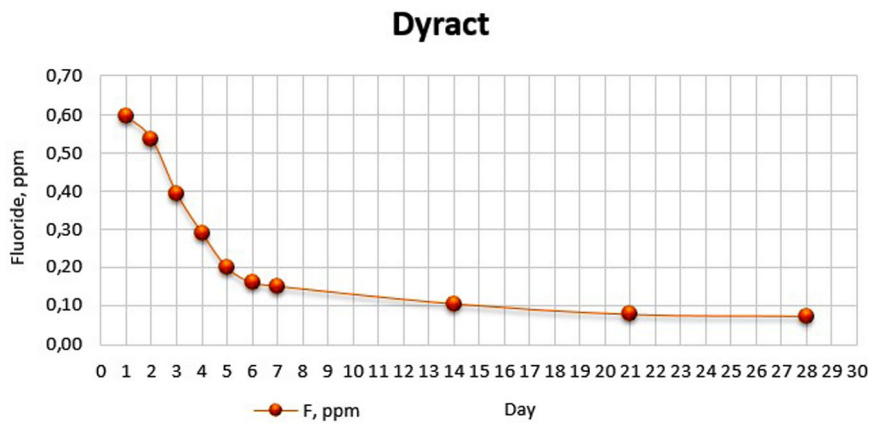
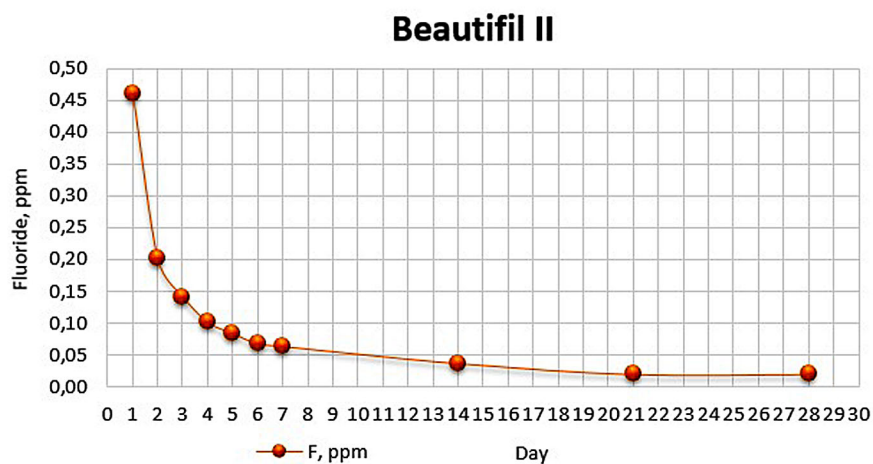


Fig. 5. Fluoride release pattern of Beautifil II



DISCUSSION

The aim of this study was to evaluate the rate and duration of fluoride release from three restorative materials in relation to their possibilities for the prevention of secondary carious lesions development. Evaluation of the ability to release fluoride ions will increase our know-

ledge of the anticariogenic effect of the tested materials and will determine indications for their use in order to reduce the risk of developing a secondary carious lesion.

It has been found that fluoride releasing materials may serve as a fluoride reservoir, which determines their preventive effect [2]. The released fluoride ions can sup-

press the demineralization process occurring under the action of the acids produced by the cariogenic bacteria in dental biofilm [2, 5, 12, 13, 14]. Fluoride present in low concentrations in the oral fluids during an acidic challenge is able to absorb the surface of the apatite crystals, thus inhibiting demineralization [5]. Another mechanism of action of fluoride ions in the composition of restorative materials is the stimulation of remineralization processes in the dental structures with which they are in contact [5, 12, 13, 14]. They inhibit bacterial activity, metabolism and growth of cariogenic microorganisms [2, 3].

As a disadvantage of the incorporation of fluoride ions in restorative materials, it is noted that the increase in its amount is accompanied by a weakening of the mechanical properties of the material. Thus, their application in stress bearing areas is compromised [2, 4]. It has been established that the fluoride content must be high enough to achieve a maximum preventive effect but without compromising the mechanical and physical properties [15].

Fluoride ions are incorporated in the structure of conventional GICs, resin-modified GICs, compomers and giomers [3, 4]. Fluoride ion release from these materials is a complex process involving several phases, such as diffusion of water into the material, dissolution of fluoride in the solid and its subsequent diffusion out of the material into the solution [6].

Dental materials releasing fluoride ions show the highest activity on the first day after setting, followed by a gradual decrease in the number of ions released over the following days, months and years [6]. The results of our study are in accordance with this statement - all three materials release the highest levels of fluoride ions during the first day of the study, after which the release slows down and continues at relatively constant levels (table 2, fig. 2).

The release of fluoride ions from GICs occurs initially as a rapid, intense release ('early burst') during the first 24-48 hours, followed by a prolonged emission at lower levels [7, 9]. This initial intense release represents the release of fluoride loosely bound in the GIC and originates from the initial acid-base reaction between the glass and polyalkenoic acid inherent to the material [3, 16]. The subsequent delayed release results from the diffusion of the fluoride ions through the cement matrix [16]. The initial intense release of these ions may also be due to surface leaching, while its subsequent stabilization results from the diffusion of fluoride ions through the pores and fractures of the material [1, 15]. The initial "burst effect" is a beneficial phenomenon as it reduces the vitality of MOs that may have remained in the dentinal tubules of the affected dentin or residual partially infected dentin and induces enamel/dentin remineralization adjacent to the restoration [15]. The results of our study confirm the proceeding of this initial, intense release of fluoride ions from the GIC (table 2, fig. 2, fig. 3). "Burst effect" is also observed with the Beautifil II (table. 2, fig. 5). This result is not in line with the results of other studies, according to which the "burst effect" is typical only for GICs [17].

The reasons for this may be due to differences in the design of the study implementation methodology. In our opinion, this result is not surprising considering that giomers are a generation of restorative materials that are enriched with fluoride ions, and their ability to release them and favor the remineralization of dental structures in contact with the restoration is indicated as their important quality [8, 9, 15].

Numerous comparative studies have been conducted on the number of fluoride ions released by different restorative materials, and the prevailing opinion is that the GICs have the greatest potential for releasing fluoride ions, followed by resin-modified GICs, compomers and composite resins [6, 9, 17]. Our results confirm that statement, as Fuji IX GP Extra has released statistically significantly the highest amount of fluoride ions for all time intervals. The reason for the large difference in the amounts of fluoride ions released between GIC and other materials lies in their chemical structure (table. 1) [15, 17].

In conventional GICs, after mixing the powder and the liquid, an acid-base reaction takes place between the polyalkenoic acid and the fluoroaluminosilicate glass [17, 18]. This results in the release of fluoride ions from the glass particles [17, 18].

Compomers, designed to combine the advantages of GIC (fluoride release) and composite resins (good physical properties), contain all the main ingredients of both materials except water [4, 8, 9]. Dyract contains acid-soluble, fluoride-containing glass particles and an acid capable of reacting with them but does not contain the water necessary for the acid-base reaction to occur [15]. During the period between the setting of the material and before contact with water has occurred, the fluoride in the composition of the compomer is not free but is bound in the filler particles surrounded by a polymerized matrix [15]. This does not allow the acid-base reaction to proceed, and at this point, the compomer behaves more like a composite than a GIC in terms of fluoride release [9, 15]. Over time, fluoride release rates from the compomer increase, and this is due to the diffusion of water into the material [9, 17]. The presence of water provides the hydrogen ions needed to break down the fluoride-containing glass particles and release fluoride ions [9]. However, the reaction is weak and does not lead to an intense release of fluoride ions [9]. There are also statements that, although compomers release low levels of fluoride ions during the first year after their placement, after that, the release increases and the levels of fluoride released become comparable to those of GICs [9, 16]. A specific feature of Dyract XP is the additional strontium fluoride included in its structure, which facilitates the release of fluoride [19]. Furthermore, the filler particle size is limited to 0.8 μm , which is also assumed to stimulate the release of fluoride ions [19]. These characteristics could explain the more intense release of fluoride ions from the compomer compared to the giomer in the current study.

The chemical structure of the giomers is a combination of fluoroaluminosilicate glass, polyalkenoic acid

and water, with resin included. What differentiates giomers from other fluoride-containing restorative materials is that they contain a pre-reacted glass (S-PRG) filler in their matrix [20]. This filler facilitates the release of fluoride ions and contributes to improving the mechanical and aesthetic properties of the material [20]. Thanks to it, in Beautifil II, the absorption of water from the surrounding area is not critical for the acid-base reaction and the release of fluoride ions [15]. According to some authors' statements, the intense acid-base reaction and the hydrogel layer of the glass particles are responsible for the higher fluoride release rates in these materials compared to compomers [17]. The results of other studies point to the opposite - according to them, compomers are more effective in releasing fluoride ions than giomers [15]. According to the results of our study, the compomer released more fluoride ions for all time intervals, but the difference was not statistically significant (table 2).

The greater porosity of GIC, compared to compomer and giomer, also explains the significantly more intense release of fluoride ions from this material [15]. In an effort to overcome the bad mechanical properties of GICs, compomer and giomer have a resin incorporated into their structure that further hinders the diffusion of water and fluorides [15].

When interpreting the results of our study, it should be taken into account that fluoride release is a complex process that is affected by factors such as matrix, filler composition, storage medium, saliva composition and acidity, temperature, preparation technique, ratio powder:

liquid, the formation of dental biofilm and pellicle, etc. [5, 6]. The reasons for the obtained differences in the results of the various studies may lie in different methodologies, sample sizes, different storage media and medium replacement frequency, and other specifics of the chosen methodology. It should also be considered that the results were obtained in experimental conditions that cannot completely reproduce the conditions of the oral environment.

CONCLUSION

All three tested restorative materials released fluoride ions throughout the study period, and the release levels decreased at different rates from the first to the 28th day. Fuji IX GP Extra is superior to compomer and giomer in terms of fluoride release. The difference between compomer and giomer is not statistically significant.

It should be noted that the release of fluoride ions is not sufficient for the prevention of secondary carious lesion. In addition, the superiority of GIC in terms of fluoride release is accompanied by important disadvantages, such as the weakening of the mechanical properties of the material and the impossibility of its application in stress bearing areas, low abrasion resistance and unsatisfactory aesthetics. Compomers and giomers outperform GIC in all these indicators [9, 10].

Abbreviations

GIC - glass-ionomer cement

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