Amounts of Fluoride Recharge in Three Glass Ionomer Luting Agents in Different Times

Mohammad Hassan Salari [1], Shirin Lavvaf [1], Faezeh Shahnazi [2], Behzad Salari [3,*]

1. Department of Prosthodontics, School of dentistry, Islamic Azad University, Iran.
2. Private Dentist.
3. School of Dentistry, International Campus of Tehran University of Medical Sciences, Iran.

A B S T R A C T

Purpose: In order to decrease the risk of dental caries and improve exposure of the teeth to fluoride, glass ionomer cements were introduced in restorative dentistry. Since fluoride releases from some dental materials, the gradual reuptake ability of fluoride in these cements is important in the long-term. In this study we intended to compare the amount of fluoride release in three common glass ionomer cements (FUJI 1, SDS, and FUJI PLUS) at 1,3,7,14 and 28 days.

Methods: First, 24 disc shaped samples were fabricated from FUJI 1, SDS and FUJI PLUS glass ionomer cements. The discs were, then, drained from fluoride ions in a period of 56 days. Discs were randomly selected and, then, divided into control and experimental groups. In the experimental groups, each sample was dried and exposed to Colgate Total 1000 ppm fluoride toothpaste; afterwards, they were washed and stored in distilled water at 37°C. Amounts of fluoride ion release were evaluated at 1, 3,7,14 and 28 days for all the experimental samples. In the control groups, the same procedure was done but with no exposure to fluoride. Differences in the release of fluoride ion from the tested products were evaluated using two-way analysis of variance (ANOVA) and the mixed model. A P- value of <0.05 was considered statistically significant.

Results: There were statistically significant differences between the experimental and control groups in all three materials during the 28-day experiment. The amount of fluoride release increased from day 1 to 7 and then decreased up to day 28. On days 1, 3 and 7, SDS had the largest and Fuji I had the lowest amount of fluoride release and on days 14 and 28 the largest amount of fluoride release was seen in FUJI PLUS, SDS and FUJI I, respectively.

Conclusion: SDS as a newly released and less expensive glass ionomer can release fluoride ions as effectively as FUJI PLUS. All glass ionomer cements evaluated in this study may be effectively recharged with fluoride ions in order to effectively release them in time to aid tooth remineralization.

1. Introduction

Fluoride release from dental materials is recognized as a protective element for teeth against caries; it prevents demineralization and facilitates remineralization of tooth structure [1]. Even small amounts of fluoride-contacting tooth structure can play a major role in the reduction of secondary caries. Considering the beneficial properties of fluoride in dentistry, many investigations have been carried out on this issue[2]. Forstenl and Takahashi were the first to investigate patterns of fluoride reuptake by dental materials [3, 4].

* Corresponding Author:
Behzad Salari, DDS
School of Dentistry, International Campus of Tehran University of Medical Sciences, Tehran, Iran..
Tel: +98 21 88712674
E-mail: b.salarii@gmail.com

Properties of cements in restorative dentistry could have a great impact on the prognosis of the final restorations. The glass ionomer (GI) cements were developed in 1972 by Wilson and Kent [5] in order to overcome the major clinical limitations of silicate cements, namely their solubility in the oral environment and pulpal toxicity . One of the important properties of the GI cements, as with the silicate cements, is their ability to release fluoride [6, 7].The release of fluoride from the GI cements may exert a cariostatic effect by reducing enamel solubility in acid [8], increasing fluoride concentration of the adjacent dental tissues[9], enhancing enamel microhardness [10], elevating plaque fluoride level [11, 12] inhibiting growth of S. mutans [13], and inhibiting caries-like lesion formation[14].

Glass ionomers can also reuptake fluoride from the external sources to substitute their lost fluoride content [2, 15]. This recharge of fluoride in the GI-based materials may contribute to the ability of these materials to retain their anticariogenic effects for a long-term [16]. Frosten et al. proved that fluoride release could continue for 5 years, but in very small amounts [17].The precise nature of the mechanism of recharging is not fully clear; but it has been suggested that the recharging ability of the glass ionomer cements depends on the glass component of the material and, in particular, upon the structure of the hydrogel layer around glass filler particles following reactions between the glass and polyacid components[18, 19].

Investigations showed that after releasing high amounts of fluoride from the GI-containing materials, the rate of fluoride release stayed constant for about 3 weeks[20, 21]. Fluoride could be reuptaken by various external sources such as toothpastes, mouth washes and topical gels. Toothpastes were the most common source and NaF gel was recognized as the largest source of fluoride [2, 22]. Meyer and Arbabzade revealed that due to adhesive properties of toothpastes and their potential to cover the teeth's porosities, they were the most effective vehicles to recharge glass ionomers[23].

The properties such as the amount of external fluoride, type and viscosity of the external fluoride in the environment, pH of the environment and permeability of materials are factors affecting recharge of GI dental materials[24]. Kent and Wilson explained fluoride release by three mechanisms: surface wash-off, dissolution of fluoride from the cracks and fissures and dissolution of fluoride by solid state diffusion from the bulk; the first mechanism caused the greatest amount of fluoride re-lease and the other mechanisms had lesser effects [25]. The exact amounts of fluoride needed to provide long term effects of GI cements were not mentioned clearly in previous studies; but it was proven that as more fluoride is released from dental materials, their ability to reduce secondary caries is increased [21, 24, 26]. The aim of this study was to compare the amount of fluoride reuptake by the two popular GI cements and a recently introduced and less expensive glass ionomer cement in different periods.

2. Materials and Methods

In this study 24 samples of glass ionomer cements were prepared in special stainless steel moulds (8*5 cm) with holes (10 mm diameter and 3 mm depth) in the center of each mold. Moulds were filled with glass ionomer cements [SDS (Lot 3241415; Salamifar Company, Tehran, Iran), Fuji PLUS (Lot 0612121; GC Dental Product Corp, Tokyo, Japan) and Fuji I (Lot 75784040; GC Dental Product Corp, Tokyo, Japan)]. Cements were mixed according to the manufacturer's instructions (Table 1); all moulds sustained pressure until the setting time for each cement was complete.

Eight samples were fabricated from each glass ionomer cement. Immediately after fabrication, samples were stored in distilled water in an incubator (Heratherm IMC18, USA) at 37°C; discs were drained of fluoride content in a period of 56 days. For each glass ionomer cement the recharged discs were randomly divided into two groups, namely experimental and control groups (n=4), then stored in the tubes containing 4 mL of distilled water in an incubator (Heratherm IMC18, USA) at 37°C. Distilled water in the tubes was replaced every 24 hours. The discs in the experimental groups were dried for 2 minutes with tissue papers and then exposed to 1450 ppm fluoride Colgate Total toothpaste (Lot 071100700; Palmolive, USA). The upper and lower faces of the discs were covered with a layer of toothpaste; the discs were then washed with distilled water for 10 seconds, dried and stored in new tubes containing 4mL of distilled water in an incubator (Heratherm IMC18, USA) at 37°C. The amounts of fluoride ions were measured by potentiometer (Model 96-09-00, Orion Research Inc., and Cambridge, MA, USA) on days 1, 3,7,14 and 28.

10 mL of TISAB (total ionic strength adjustment buffer) was added to the tubes before using the potentiometer in each tube in order to stabilize the pH and eliminate the influence of foreign ions during the examination.

The samples in the control groups were not exposed to toothpaste; they were stored in tubes containing 4mL of distilled water, in an incubator (Heratherm IMC18, USA) at 37°C. The measurement of fluoride ions in samples was done at days 1, 3,7,14 and 28 with a potentiometer (Model 96-09-00, Orion Research Inc., Cambridge, MA, USA). 10 mL of TISAB (total ionic strength adjustment buffer) was added to tubes before using the potentiometer in each tube in order to stabilize the pH and eliminate the influence of foreign ions during the examination.

For homogenous diffusion of the fluoride ions in the tubes, all the tubes were vibrated while electrodes of potentiometer were in use. Electrodes were washed with large amounts of distilled water between the different tubes.

In the experimental groups, the amount of fluoride release was evaluated in a period of 28 days following the exposure of samples to the fluoride containing toothpaste. The amount of fluoride release was also evaluated in the control groups which were not exposed to the fluoride containing toothpaste in the same period. Data were expressed as mean and standard deviation (SD) and were analyzed using the analysis of variance (ANOVA) and mixed model. P value <0.05 was considered statistically significant.

Table 1. The manufacturers' instructions for mixing the materials

Commercial Names	Type of Glass Ionomer Cement	P/l ratio	Mixing Time	Setting Time
FUJI1	Conventional glass ionomer	1 spoon powder, 2 drops of liquid	20 seconds	2 minutes
FUJI PLUS	Resin modified glass ionomer	1 spoon powder, 3 drops of liquid	20 seconds	2 minutes
SDS	Conventional glass ionomer	1 spoon powder,3 drops of liquid	15 seconds	12 minutes

3. Results

There were statistically significant differences between the study and control groups in all three materials (SDS, FUJI I and FUJI PLUS) during the 28 days of experimentation. The experimental groups released much more fluoride than controls (Table 2). In the control groups, the average amount of fluoride release in all three materials decreased during the 28 days. Fuji PLUS had the largest and Fuji I had the lowest amounts of fluoride release (P<0.0001). There were statistical differences between all experimental groups (SDS, Fuji I and Fuji PLUS, Figure 1). The amount of fluoride release increased on days 1 to 7 and then decreased up to the day 28 (P<0.0001, Figure 1). The statistical results of the mixed model test in the experimental groups in this period showed significant statistical differences, on days 1, 3 and 7. SDS had the largest and Fuji I had the lowest amounts of fluoride release (P<0.0001); on days 14 and 28 the largest amount of fluoride release was seen in the FUJI PLUS, SDS and FUJI I, respectively (Figure 1).

Table 2. The amount of fluoride release from different groups

| Fluoride / Time	SDS		Fuji 1		Fuji PLUS		P value
	Test Mean±SD (ppm)	Control Mean±SD (ppm)	Test Mean±SD (ppm)	Control Mean±SD (ppm)	Test Mean±SD (ppm)	Control Mean±SD (ppm)	
Day 1	86.12±0.29	1.30±0.21	24.17±0.31	0.44±0.22	40.29±0.49	2.01±0.06	0.0001
Day 3	135.30±0.18	1.02±0.06	46.10±0.04	0.28±0.12	81.01±0.21	1.43±0.21	0.0001
Day 7	145.04±0.15	0.76±0.13	55.49±0.40	0.18±0.04	95.23±0.27	1.24±0.33	0.0001
Day 14	45.96±0.19	0.36±0.34	31.43±0.75	0.12±0.19	52.01±0.11	0.83±0.42	0.0001
Day 28	35.24±0.31	0.11±0.10	22.10±0.28	0.06±0.41	40.01±0.13	0.21±0.14	0.0001
P value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
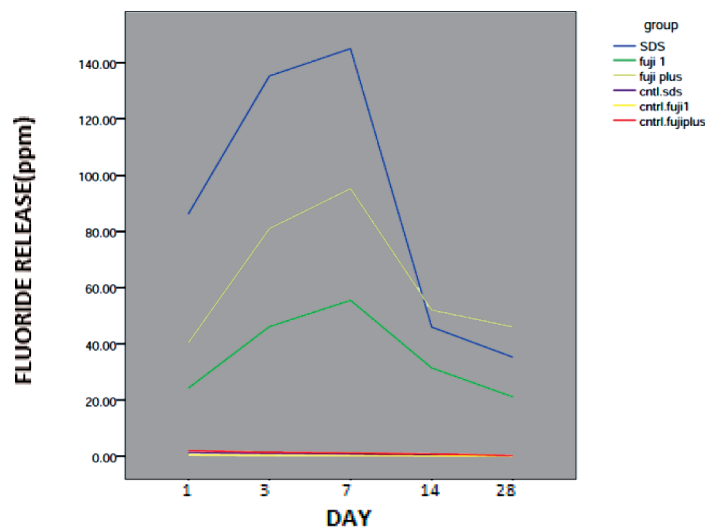
Figure 1. The amount of fluoride release in the experimental and control groups

4. Discussion

In this study, we aimed to evaluate the amount of fluoride reuptake by three glass ionomer cements (SDS, Fuji I and Fuji PLUS) in order to foresee their long-term fluoride release behavior.

In the control groups, some amounts of fluoride release were seen in all three materials but in very small amounts; such small amounts of fluoride release can be attributed to the fact that we discharged most of the fluoride content stored in samples in 56 days. However, it seemed impossible to eradicate fluoride from samples because fluoride is a structural ion of the glass ionomer cements [27].

Fluoride release showed both fast and slow releasing patterns; the fast release was mostly seen in the first 24 to 48 hours and the long-term and continuous pattern of release occurred after that [28, 29]. Diazarnold and Verbeeck proved that in the first step, due to reaction between glass particles and poly alkanoic acid, large amounts of fluoride release were seen rapidly. In the second step, due to the interaction between glass particles and the structure of the material, fluoride release decreased [30, 31] as we saw in our study.

In this study, all experimental groups had the same pattern of fluoride ion release, the ascending path was seen at first (days 1 to 7) and afterwards the descending path (days 7 to 28).This unique pattern could be attributed to the ion saturation and surface energy level of glass samples [32]. Mousavinasab et al. reported a progressively

descending pattern of fluoride ion release in a similar study [33] but another investigation around the recharge of dental materials showed a progressively ascending pattern of fluoride release; these controversies could be attributed to the different glass ionomer cements investigated in these studies.[33]

Different investigations used different materials as sources for glass ionomer cements' recharge, we used a toothpaste containing 1450 ppm sodium fluoride for this goal because of its effectiveness and prevalence. Some investigations showed that fluoride ion concentration, type and viscosity of recharging source could affect the results of investigations ,they mentioned that APF gel was more effective than NaF, this predominance was attributed to the structure of APF gels consisting of phosphoric acid and their insolvable matrix, but Meyers et al. believed that toothpastes were more effective due to their sticky nature [23, 34].

Temperature, powder/liquid ratio, mixing time, setting time and porosity of the material are factors that affect fluoride release from dental materials[24]. On days 1, 3 and 7, SDS had the largest and Fuji I had the lowest amount of fluoride release; these differences in the amount of fluoride release may be attributed to the physical properties of SDS (possibly because SDS has more porosities in its structure causing more fluoride release, other attributing factors were managed to be the same among experimental groups). Previous studies proved that porosities facilitate entrance of solutions and ions into dental materials; thus, more fluoride may be released and reuptaken [35].

Result of our study in controls revealed that all three cements could release and reuptake fluoride; this result confirms previous studies [1, 21, 22].

The mechanism of fluoride release has not been fully understood yet; but this procedure is dependent on the factors such as the density of fluoride in the solution, viscosity, type and pH of fluoride solution and permeability of the dental material [1, 36, 37]. In our study, on days 14 and 28 the largest amount of fluoride release was seen in FUJI PLUS, SDS, and FUJI, respectively. However, on days 1, 3 and 7 SDS had the largest and FUJI I had the lowest amount of fluoride release; this transposition between SDS and FUJI PLUS may be attributed to the unavoidable changes in the environment such as the concentration of released fluoride ion around samples [2, 36, 38, 39].

The greater ability of SDS to release and reuptake fluoride on days 1,3 and 7 could be attributed to the porous surface and the greater ability of this cement to store fluoride ions than FUJI PLUS and FUJI I [40].

Marginoff and Eichmiller proved that the ability to prevent caries and remineralize the dental structure in glass ionomer cements occurred when the fluoride release was done with the frequency of 1mg/L, 3ppm fluoride caused changes in the demineralization procedure towards remineralization [41]; by this criterion all the samples in our study (SDS, FUJI PLUS and FUJI I) could prevent dental caries and activate the remineralization process.

Studies proved that fluoride release from glass ionomer cements decreased sizably after the elimination of fluoride sources, it suggested that continuous fluoride saturation around glass ionomer cements was required for effective service of these cements [37, 42].

5. Conclusion

A comparison of fluoride release between SDS, FUJI PLUS and FUJI I during 28 days of experimentation revealed that:

All three materials could effectively reuptake fluoride ions from fluoride enriched tooth paste.

All cements used in this investigation may have the ability to prevent caries and remineralize the tooth structure in-vivo.

All three materials may preserve their anti-caries and remineralization properties for a long period of time.

SDS, as a newly released and less expensive glass ionomer, functioned as well as FUJI PLUS.

More long-term investigations are needed to uncover the mechanisms of fluoride reuptake by the glass ionomer cements.

References

[1] S. Hatibovic-Kofman, et al., "Glass ionomer materials as a rechargeable fluoride-release system," Int J Paediatr Dent, vol. 7, pp. 65-73, Jun 1997.

[2] A. J. Preston, et al., "The recharge of esthetic dental restorative materials with fluoride in vitro-two years' results," Dent Mater, vol. 19, pp. 32-7, Jan 2003.

[3] L. Forsten, "Fluoride release and uptake by glass ionomers," Scand J Dent Res, vol. 99, pp. 241-5, Jun 1991.

[4] K. Takahashi, et al., "Fluoride release in vitro from various glass ionomer cements and resin composites after exposure to NaF solutions," Dent Mater, vol. 9, pp. 350-4, Nov 1993.

[5] A. D. Wilson and B. E. Kent, "A new translucent cement for dentistry. The glass ionomer cement," Br Dent J, vol. 132, pp. 133-5, Feb 15 1972.

[6] M. L. Swartz, et al., "Long-term F release from glass ionomer cements," J Dent Res, vol. 63, pp. 158-60, Feb 1984.

[7] M. Cranfield, et al., "Factors relating to the rate of fluoride-ion release from glass-ionomer cement," J Dent, vol. 10, pp. 333-41, Dec 1982.

[8] M. A. Buzalaf, et al., "Mechanisms of action of fluoride for caries control," Monogr Oral Sci, vol. 22, pp. 97-114, 2011.

[9] J. W. Nicholson and B. Czarnecka, "Maturation affects fluoride uptake by glass-ionomer dental cements," Dent Mater, vol. 28, pp. e1-5, Feb 2012.

[10] H. Forss and L. Seppa, "Prevention of enamel demineralization adjacent to glass ionomer filling materials," Scand J Dent Res, vol. 98, pp. 173-8, Apr 1990.

[11] A. Hallgren, et al., "Fluoride concentration in plaque adjacent to orthodontic appliances retained with glass ionomer cement," Caries Res, vol. 27, pp. 51-4, 1993.

[12] G. M. Whitford, et al., "Plaque fluoride concentrations are dependent on plaque calcium concentrations," Caries Res, vol. 36, pp. 256-65, Jul-Aug 2002.

[13] T. Walsh, et al., "Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents," Cochrane Database Syst Rev, p. CD007868, 2010.

[14] R. G. Rozier, et al., "Evidence-based clinical recommendations on the prescription of dietary fluoride supplements for caries prevention: a report of the American Dental Association Council on Scientific Affairs," J Am Dent Assoc, vol. 141, pp. 1480-9, Dec 2010.

[15] A. J. Preston, et al., "Fluoride recharge of aesthetic dental materials," J Oral Rehabil, vol. 26, pp. 936-40, Dec 1999.

[16] A. R. Vieira, et al., "Fluoride uptake and release by composites and glass ionomers in a high caries challenge situation," Am J Dent, vol. 12, pp. 14-8, Feb 1999.

[17] L. Forsten, "Fluoride release and uptake by glass-ionomers and related materials and its clinical effect," Biomaterials, vol. 19, pp. 503-8, Mar 1998.

[18] N. Attar and A. Onen, "Fluoride release and uptake characteristics of aesthetic restorative materials," J Oral Rehabil, vol. 29, pp. 791-8, Aug 2002.

[19] L. Han, et al., "Effect of fluoride mouth rinse on fluoride releasing and recharging from aesthetic dental materials," Dent Mater J, vol. 21, pp. 285-95, Dec 2002.

[20] P. Neelakantan, et al., "Fluoride release from a new glass-ionomer cement," Oper Dent, vol. 36, pp. 80-5, Jan-Feb 2011.

[21] F. B. de Araujo, et al., "Fluoride release from fluoride-containing materials," Oper Dent, vol. 21, pp. 185-90, Sep-Oct 1996.

[22] C. J. Palenik, et al., "Inhibition of microbial adherence and growth by various glass ionomers in vitro," Dent Mater, vol. 8, pp. 16-20, Jan 1992.

[23] F. Arbabzadeh-Zavareh, et al., "Recharge pattern of contemporary glass ionomer restoratives," Dent Res J (Isfahan), vol. 9, pp. 139-45, Mar 2012.

[24] M. Shiozawa, et al., "Fluoride release and mechanical properties after 1-year water storage of recent restorative glass ionomer cements," Clin Oral Investig, Aug 22 2013.

[25] J. W. McLean, et al., "Proposed nomenclature for glass-ionomer dental cements and related materials," Quintessence Int, vol. 25, pp. 587-9, Sep 1994.

[26] C. L. Davidson, "Advances in glass-ionomer cements," J Appl Oral Sci, vol. 14 Suppl, pp. 3-9, 2006.

[27] R. L. dos Santos, et al., "Long-term fluoride release from resin-reinforced orthodontic cements following recharge with fluoride solution," Braz Dent J, vol. 21, pp. 98-103, 2010.

[28] L. Forsten, "Fluoride release from a glass ionomer cement," Scand J Dent Res, vol. 85, pp. 503-4, Sep 1977.

[29] S. B. Mitra, et al., "Fluoride release and recharge behavior of a nano-filled resin-modified glass ionomer compared with that of other fluoride releasing materials," Am J Dent, vol. 24, pp. 372-8, Dec 2011.

[30] R. M. Verbeeck, et al., "Fluoride release process of (resin-modified) glass-ionomer cements versus (polyacid-modified) composite resins," Biomaterials, vol. 19, pp. 509-19, Mar 1998.

[31] A. M. Diaz-Arnold, et al., "Short-term fluoride release/uptake of glass ionomer restoratives," Dent Mater, vol. 11, pp. 96-101, Mar 1995.

[32] S. L. Creanor, et al., "Fluoride uptake and release characteristics of glass ionomer cements," Caries Res, vol. 28, pp. 322-8, 1994.

[33] S. M. Mousavinasab and I. Meyers, "Fluoride release by glass ionomer cements, compomer and giomer," Dent Res J (Isfahan), vol. 6, pp. 75-81, Fall 2009.

[34] W. Gao, et al., "Fluoride release/uptake from newer glass-ionomer cements used with the ART approach," Am J Dent, vol. 13, pp. 201-4, Aug 2000.

[35] E. Chatzistavrou, et al., "Fluoride release from an orthodontic glass ionomer adhesive in vitro and enamel fluoride uptake in vivo," Am J Orthod Dentofacial Orthop, vol. 137, pp. 458 e1-8; discussion 458-9, Apr 2010.

[36] N. Attar and M. D. Turgut, "Fluoride release and uptake capacities of fluoride-releasing restorative materials," Oper Dent, vol. 28, pp. 395-402, Jul-Aug 2003.

[37] J. Burgess, et al., "Resin ionomer restorative materials: the new generation," J Esthet Dent, vol. 6, pp. 207-15, 1994.

[38] Z. Bilgin and N. Ozalp, "Fluoride release from three different types of glass ionomer cements after exposure to NaF solution and APF gel," J Clin Pediatr Dent, vol. 22, pp. 237-41, Spring 1998.

[39] M. A. Paschoal, et al., "Fluoride release profile of a nano-filled resin-modified glass ionomer cement," Braz Dent J, vol. 22, pp. 275-9, 2011.

[40] E. Gjorgievska, et al., "Erratum to: Ion migration from fluoride-releasing dental restorative materials into dental hard tissues," J Mater Sci Mater Med, Sep 21 2013.

[41] F. C. Eichmiller and W. A. Marjenhoff, "Fluoride-releasing dental restorative materials," Oper Dent, vol. 23, pp. 218-28, Sep-Oct 1998.

[42] K. J. Donly and J. J. Nelson, "Fluoride release of restorative materials exposed to a fluoridated dentifrice," ASDC J Dent Child, vol. 64, pp. 249-50, Jul-Aug 1997.