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Original Article

Fluoride release from three glass ionomers after exposure to sodium fluoride and acidulated phosphate fluoride gels

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ABSTRACT

Background: Glass ionomer (GI) restorations exposed to fluoride have the ability to slowly release fluoride. Therefore, the aim of this study was to investigate fluoride release from three GIs before and after exposure to sodium fluoride (NaF) and acidulated phosphate fluoride (APF).
Materials and Methods: Fifteen disc-shaped samples (6 mm in diameter and 2 mm in thickness) from three GIs (Fuji II, Fuji IX, Chem Flex) were made and suspended in a polypropylene recipient containing 10 mL distilled water and stored at 37°C. At the 13th day, the samples of each GI were randomly divided into 3 groups. Groups 1 and 2 were exposed to NaF and APF gels for 4 min and group 3 served as control in distilled water. The fluoride released was measured at day 1, 4, 10, 13, 14, 17, 20 and 23 by potentiometer. Data were analyzed by one-way ANOVA and Tukey test. $P < 0.05$ was considered as significant.
Results: Fluoride release was highest after 24 h for the tested GIs, but Fuji II demonstrated the least amount. Fuji IX showed the highest fluoride release followed by Chem Flex. Exposure to fluoride gels significantly increased fluoride release for all materials ($P < 0.05$). The amount of fluoride release for the three GIs was significantly higher in APF groups during the test period.
Conclusion: Highly viscous conventional GIs (Fuji IX and Chem Flex) released higher quantity of fluoride.

Key Words: Acidulated phosphate fluoride, dental caries, fluoride release, glass ionomer, sodium fluoride

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INTRODUCTION

Although great advances have been made in the field of oral health in the world, dental caries remains a significant problem world-wide.[1] Fluoride-releasing restorative materials applied in dentistry, with regular release of small amounts of fluoride in the oral cavity, act as caries preventive systems.[2] Among these restorative materials, glass ionomers (GIs) release higher amount of fluoride and composite resins containing fluoride have lower fluoride release.[2,3] GIs have the ability to release fluoride[4-6] and this fluoride release is considered as one of the main advantages of GIs.[3] Based on antimicrobial activity of GI, these restorative materials prevent the occurrence of secondary caries.[7,8]

Furthermore, studies have shown that GIs, in addition to fluoride ion release properties, have the potential to reuptake fluoride ion and that fluoride recharge can be more important than fluoride release. Laboratory studies have indicated that GIs can uptake from various sources such as toothpastes and mouthwashes. Absorbed fluoride is stored and gradually released. Even some of the old versions of GIs have the ability to recharge and release fluoride and as long

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as the restoration is in place, it maintains anti-caries properties. Presence of fluoride in the oral environment assures long-lasting fluoride release, since fluoride is attached to GI by chemical bonds and then progressively released.[3,9-11]

Considering the aforementioned information, the effect of type of GIs and fluoride therapy on the fluoride release is somewhat unclear. Therefore, the aim of this study was to determine and compare the fluoride release of three different GIs (Fuji IX, Chem Flex and Fuji II) in deionized water with different recharge sources of fluoride, acidulated phosphate fluoride (APF) and sodium fluoride (NaF) gels.

MATERIALS AND METHODS

In this *in vitro* study, the amount of fluoride release was evaluated for three GIs, Fuji IX, Chem Flex and Fuji II after exposure to NaF 2% and APF 1.23% gels, taking into account type I error ($\alpha = 0.05$) and type Π error ($\beta = 0.1$, power = 0.9) as well as using the results of a previous study, the estimated standard deviation and the mean values of fluoride released from each type of GI. The number of samples in every subgroup was evaluated 3 and for more accuracy it was considered 5. Hence, the total number of samples in all GI groups was considered 15. Fifteen disc-shaped samples with 6 mm diameter and 2 mm thickness were prepared using a frame made of Perspex according to the manufacturer's instructions. To immerse samples in the deionized water, a piece of dental floss without fluoride was anchored within each sample. The surfaces of samples were put under steady pressure with a transparent matrix and glass slide during polymerization. The samples remained under the matrix for 10 min at room temperature. Then, all samples were separately immersed in the plastic bottles containing 10 ml deionized water and were first kept in humid and at 37°C temperature for an hour. After that, all samples were separately transferred to a new plastic bottle containing 10 ml deionized water and replaced in humid environment and at 37°C for 24 h. During the 23 days trial period, the deionized water was daily changed by moving each sample to a new bottle containing 10 ml fresh solution.

Fluoride release was measured at days 1,4,7,10 and 13 using the potentiometry method by fluoride specific electrode (QSE 333) and reference electrode (Jenway Ag-Agcl), which were attached and connected to a pH-Ion digital device (PH-ION:025867 Micro 2; EDT instrument, England). After preparation, the 15 discs of each experimental GIs were randomly divided into 3 groups of 5 discs. One group was assigned as control and after wiping up the samples by a filter paper, they were re-immersed in a new solution of 10 ml deionized water. In the second group, having been wiped up the same way, the samples were exposed to NaF gel 2% (DENTSPLY, Latin America) for 4 min and dried again with filter paper and replaced in a new solution of 10 ml deionized water. For the third group, the samples were dried by the filter paper and exposed to APF gel 1.23% (CINA BARTAR Co., Iran) for 4 min, wiped up again with filter paper and replaced in a new solution of 10 ml deionized water. Following this, all sample bottles were put back in the humid environment at 37°C temperature for 24 h and the deionized water was daily renewed for the remaining period of experiment.

In order to measure the amount of released fluoride, TISAB II solution was added to produce an appropriate pH for fluoride electrode activity and ion strength regulation. Then, the solution was mixed by a magnetic stirrer and the amount of fluoride was determined using a specific fluoride electrode. The millivoltage of the solutions was obtained by the device and compared to millivoltages of the standard solutions after calibration curve was drawn. The obtained values from the samples were then converted to the fluoride concentrations. After the first stage in the second period, the re-release of fluoride from the samples after exposure to NaF and APF gel was measured in the same way on days 14, 17, 20 and 23.

The means and standard deviations of fluoride release were calculated for the three GIs. One-way ANOVA and Tukey tests were applied in order to analyze the data. $P < 0.05$ was considered as significant.

RESULTS

The amounts of fluoride released from Fuji II, Fuji IX and Chem Flex after exposure to NaF and APF gels are respectively shown in Figures 1-3 and Table 1.

The results of one-way ANOVA showed a significant difference between daily values of fluoride released from the three GIs before exposure to fluoride. However, the finding obtained from Tukey test indicated that the three types of GIs (Fuji II, Fuji IX and Chem Flex) significantly released more

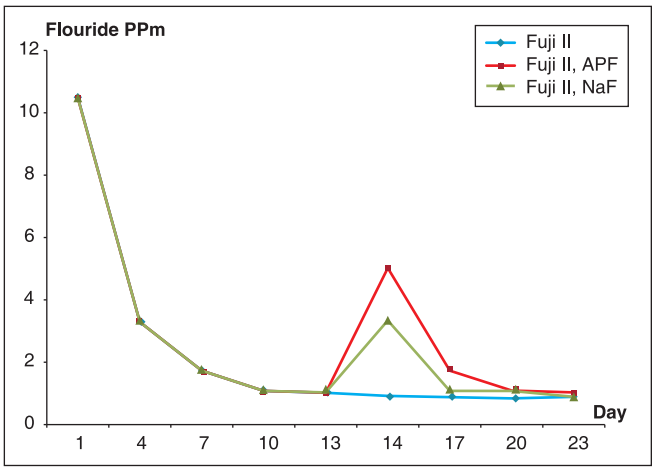

Figure 1: Fluoride released from Fuji II while exposed to acidulated phosphate fluoride and sodium fluoride

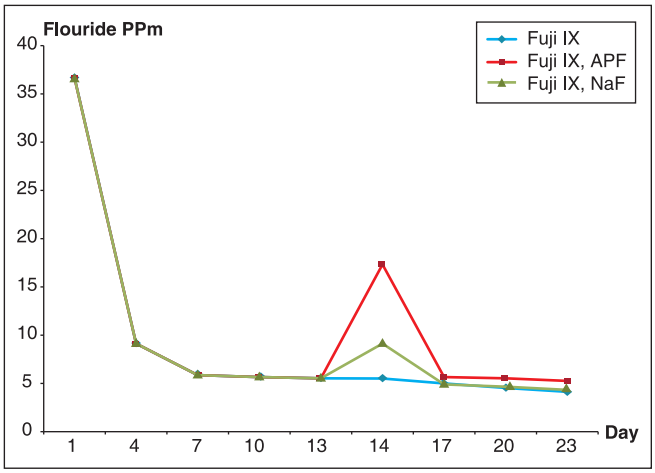

Figure 2: Fluoride released from Fuji IX while exposed to acidulated phosphate fluoride and sodium fluoride

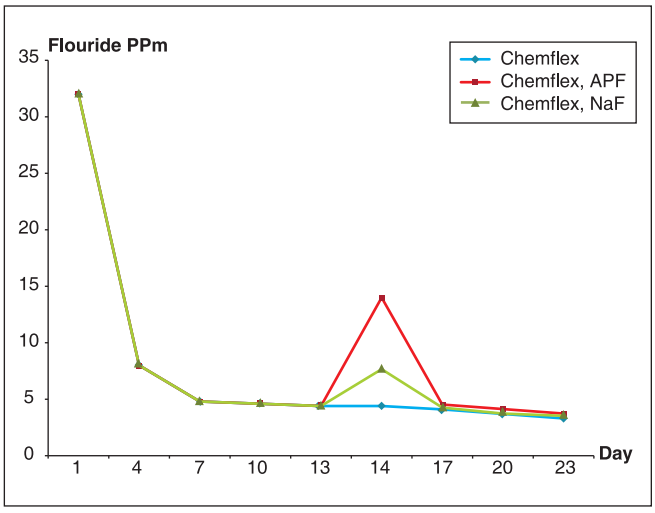

Figure 3: Fluoride released from Chem Flex while exposed to acidulated phosphate fluoride and sodium fluoride

fluoride on the 1st day than the 4th day. Further, the results of Tukey test for the mean difference, with 95% confidence interval, revealed that the fluoride levels released from Chem Flex and Fuji IX were significantly higher than that of Fuji II ($P < 0.05$). Also, the re-release of fluoride from all GIs which were exposed to APF gel was higher than GIs samples that were exposed to NaF gel. In general, exposure to fluoride gels increased the release of fluoride from samples compared with those that were not exposed.

DISCUSSION

In previous studies, various solutions such as deionized water and artificial saliva were used to measure fluoride release.[5,12-14] Wiegand *et al*. believed that in natural conditions, the pellicle and plaque on teeth affected the release of fluoride from GI. Therefore, we cannot mimic the effect of plaque and pellicle, which act as a membrane against fluoride infusion by artificial saliva,[4] since artificial saliva is not an ideal environment to measure fluoride release from GI. In this study, deionized water was used as a storage media[15] and fluoride ion-selective electrode was used to measure the amount of released fluoride. Electrode is only capable of measuring the fluoride ions in solution; therefore, it is necessary to use a buffer solution that regulates the pH and ionic strength of the solution. In most studies,[15,16-19] TISAB II is the kind of buffer used to ionize fluoride in the solution. This solution causes ions bonded to fluoride to release. It also makes pH and ionic strength of the solution be well adjusted to ensure the best conditions to measure fluoride.[13,20]

In this study, as Diaz-Arnold *et al*. study to avoid saturated solution due to equilibrium phenomena and to obtain more accurate results, the solutions were replaced every 24 h and the amount of released fluoride was measured at specified days.[17]

This study was conducted to measure the release of fluoride in two stages: First, measuring fluoride release after preparation of Chem Flex, Fuji II and Fuji IX samples and storing them in deionized water and second, after recharging the samples through exposure to NaF and APF gels.

The results showed that at the first stage, the three GIs had the greatest amount of fluoride release in the 1st day which significantly decreased in the following days and were pan after 7-10 days. These findings were in accordance with the results of the studies conducted in this field.[4,12,14,15,21,22]

Table 1: The results for fluoride release in the tested groups in different days

Days	Fuji II, APF	Fuji II, NaF	Fuji IX, APF	Fuji IX, NaF	Chem Flex, APF	Chem Flex, NaF
1	10.48	10.4	36.66	36.66	32	32
4	3.29	3.29	9.13	9.13	8	8
7	1.73	1.73	5.86	5.86	4.8	4.8
10	1.08	1.08	5.66	5.66	4.6	4.6
13	1.02	1.032	5.53	5.53	4.4	4.4
14	5.02	3.34	17.33	9.13	14	7.66
17	1.73	1.08	5.66	4.9	4.53	4.26
20	1.09	1.08	5.53	4.66	4.13	3.73
23	1.03	0.89	26.5	4.33	3.73	3.53

APF: Acidulated phosphate fluoride; NaF: Sodium fluoride

According to Yap *et al*., high concentrations of fluoride release in the 1st day are due to significant differences in fluoride concentration of GIs in comparison with that of deionized water.[14] It should be re-emphasized that the fluoride release is a diffusion controlled phenomenon.

Based on the amount of fluoride released in the first stage, a similar pattern was found for all samples; however, Fuji IX had the highest amount of fluoride release. Fluoride release of Chem Flex was the same as the Fuji IX with little variation, but the fluoride released from Fuji II was the least with a significant difference. Results obtained in this study were in line with the findings of the studies conducted by el Mallakh and Sarkar[15] and Swartz *et al*.[16] in which highly viscous GIs released more fluoride than Fuji II.

Forsten in his study has reported that fluoride released from GIs equilibrated within a time and after 2 months the amount of fluoride release was minimal in most cases.[12] Dhull and Nandlal during a period of 30 months, reviewed the fluoride released from GI and reported that the release took place in two phases, the first phase was short and quick and the second phase was long with little changes.[18]

In the initial step of release, the three GIs showed high levels of fluoride. According to Forsten, the initial release of fluoride is desirable because it reduces the remaining viable bacteria on the border of caries lesion and stimulates enamel and dentin remineralization.[12]

Billington *et al*. in their study have reported that the fluoride release rate depends on the solution pH and in an acidic solution, the amount of fluoride released from GIs is higher.[23] It is expected that if a higher amount of fluoride is used in GIs composition, a greater fluoride will be released.[4] In the present study, evaluation of the daily values of fluoride release revealed that the three tested GIs reached a relatively constant level of fluoride release after the 1st week. These results are in agreement with the findings of Wiegand *et al*. in that the graphs of fluoride release from GIs were pan after around the 10th day.[4]

Ilie and Hickel showed that GIs have the capacity of uptaking fluoride from toothpaste and releasing this fluoride again.[9]

The three GIs were exposed to APF and NaF gels for 4 min; they were then placed in deionized water and the released fluoride was measured again. Since the recommended duration for fluoride therapy is 4 min, to achieve closer clinical conditions, the samples were exposed to fluoride gels for 4 min. It was shown that the three types of GI were able to uptake and release fluoride, which is consistent with the results of other studies.[18,24-26]

Alvarez *et al*. demonstrated that the amount of released fluoride will never achieve its initial amount, but daily exposure to fluoride will enhance the release of fluoride from these restorative materials.[24] The amount of released fluoride after exposure to fluoride gel is dependent on soluble fluoride concentration.[11,25] Therefore, it seems that the fluoride taken up after recharging occupies the sites, which have been previously occupied by fluoride, before it is released. Higher porosity will allow deeper diffusion of the recharging agent into the sample, leading to a higher amount of fluoride storage and release.[11]

Due to the high viscosity of the APF gel, it may be trapped in the pores and cracks of the specimens and consequently release fluoride ions as the gel dissolves in the artificial saliva in which it was placed. Also, the amount of fluoride-release increases when the acidic solution of 1.23% APF is used in comparison to the neutral solution of 2% NaF.[11]

Seppa stated that the exposure of old GIs to fluoride gels would amplify the antibacterial activity of GIs due to increase of fluoride release.[27] In the present study, the highest amount of fluoride was released in the first 2 days after using the gels.

The highest amount of fluoride release for the three GIs was observed after exposure to APF gel that might be due to solubility. Phosphoric acid of APF gel can cause significant solubility of cations forming the matrix.[28] Diaz-Arnold *et al*. in their study have reported that APF gel significantly reduces the hardness of the GIs and can have an impact on the longevity of restorations.[29] Although the amount of fluoride released from the three GIs after exposure to APF gel was more than that of NaF gel, the APF gel reduced the surface hardness of GIs and increased their solubility, therefore the increase that was observed in fluoride release was not associated with a true chemical recharging.[30]

In this study, three GIs were exposed to NaF gel for 4 min, fluoride was recharged and the GIs slowly released fluoride, but Freedman and Diefenderfer did not observe any significant degradation on the surface of material after exposure of GIs to NaF gel.[28]

CONCLUSION

The fluoride release pattern was similar in the three GIs. Fuji IX released higher fluoride than other GIs. Chem Flex with a slight difference and Fuji II ranked second and third, respectively. All GIs were able to uptake and release fluoride after exposure to fluoride gels. The amount of fluoride released after exposure to APF gel in the three groups was the highest. This article illustrated the importance of GIs restorations in pediatric dentistry because of their ability to release fluoride, especially after exposure to different fluoride gels.

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