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Fluoride Release and Uptake by Glass Ionomer Cements, Compomers and Giomers

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Abstarct: Daily fluoride release/uptake by glass ionomer cements, compomers and Giomers. To measure the amounts of fluoride released from fluoride-containing materials before and after fluoride applications 4 glass ionomer cements (Fuji IX, Fuji VII, Fuji IX Extra, Fuji II LC), a Compomer (Dyract Extra) and a Giomer (Beautifil) were used in this study. Cylindrical specimens prepared and the amount of released fluoride was measured during the 1st week and on the days 14 and 21 by using specific fluoride electrode and an ion-analyzer. After 21 days, the specimens divided into 1 groups each of 10. The specimens of 1 group exposed to 220 ppm Mouth wash solution and the other group specimens exposed to 1000 ppm F NaF toothpaste. Fluoride release after recharge was measured and recorded daily for a total of 7 days. The results were statistically analyzed using 2 ways ANOV A and Tukey Kramer multiple comparison tests. Significant differences were seen in fluoride release before and after recharge for different days and materials. FVII released the maximum amount of fluoride followed by FIX EX, FII LC, FIX, DE and BT. On the 21st the maximum fluoride release was related to FVII, followed by FII LC, FIX EX, FIX, DE and BT. The maximum and minimum fluoride in samples treated by mouthwash or toothpaste released by FVII and BT, respectively. The maximum amount of fluoride released by F VII and the minimum by BT before and after recharge, respectively. It seems that the extent of the glass ionomer matrix plays an important part in determining the fluoride recharging ability of GICs materials.

Key words: Fluoride, release, uptake, glass ionomer, recharge, giomer, compomer

INTRODUCTION

Today, there are several fluoride containing dental restorative materials available in the market including glass ionomer cements, resin modified glass ionomers, polyacid modified resins (compomers), giomers and composites.

Fluoride containing dental materials show clear differences in the fluoride release and uptake characteristics (Preston *et al.*, 1999; De Araujo *et al.*, 1996) and may act as fluoride reservoir to increase fluoride level in saliva, plaque and hard dental tissues, or may help to prevent or reduce secondary caries (Dunne *et al.*, 1996; Exterkate *et al.*, 2005; Pardi *et al.*, 2003; Forss *et al.*, 1991; Hattab *et al.*, 1991; Koch and Hatibovic-Kofman, 1990).

Short and long term fluoride release from restorative materials are related to their matrices, setting mechanism and fluoride content, nature of fluoride incorporated into resin based materials and also depends on several environmental condition (El Mallakh and Sarker, 1990; Horsted-Bindslev, 1994; Itota *et al.*, 2005; Wiegand *et al.*, 2007).

The pattern of fluoride release from glass ionomer cements is characterized by an initial rapid release and then is followed by a rapid reduction in the rate of release of fluoride after short time (Weidlich *et al.*, 2000; Cildir and Sandalli, 2005).

It has been shown that glass ionomer cements and resin modified glass ionomer cements have the potential for fluoride recharge (Preston *et al.*, 1999; Cildir and Sandalli, 2005; Creanor *et al.*, 1994; Delbem *et al.*, 2005).

In an *ex vivo* study comparing fluoride release behavior of a conventional glass ionomer (limerick glass) with a resin modified one (Fuji Ortho™ LC), both of test materials exhibited the classic fluoride release curve of GICs with a more sustained release for conventional over

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time. Both materials emonstrated an increase in fluoride release after recharge, but this recharge potential diminished over time and with repeated exposure to fluoride supplement (Coonar *et al*., 2001).

Esthetic filling materials vary in their capacity and pattern to absorb and re release fluoride (Young *et al*., 1996; Gao *et al*., 2000; Attar and Onen, 2002a; Hsu *et al*., 2004) fluoride release from glass ionomers after recharge is also dependent on the concentration of the original fluoride exposure (Takashi *et al*., 1993).

Increased fluoride ion release following topical exposure of the fluoridated restorative materials to APF gel is caused by surface effect rather than by chemical recharging (Gao *et al*., 2001a).

Superior recharging ability of the glass ionomer cements compared to that of compomers has been reported (Itota *et al*., 1999; Preston *et al*., 2003).

Glass ionomer based materials also display a far greater potential for fluoride recharge than composites. In a study, Attar and Onen (2002b) examined fluoride recharge of resin modified glass ionomers and a polyacid modified resin. For all materials, fluoride release increased significantly during the first 24-48 h following fluoride exposure, then declined to a constant low level, on the contrary, it is claimed that compomers can not be replenished with fluoride in other studies, Suljak and Kafman (1996) and Attin *et al*. (1999).

The ability of GIC sealants to serve as fluoride reservoir in oral cavity and retaining a low fluoride level in oral fluids has been proved in a study (Koga *et al*., 2004). A recent development has been the introduction of the Giomers materials. Variable extent of the GI phase is determined by differences in the resin composition of the restoratives (Tay *et al*., 2001).

A study has shown that the amount of total and free fluoride release from Giomer was higher than Compomer and resin composite and concluded, the extent of glass ionomer matrix of the glass filler play an important role for fluoride releasing and recharging abilities of the resin based materials (Itota *et al*., 2004a). Also it has been shown that giomers and compomers do not have the initial fluoride burst effect associated with glass ionomer cements (Yap *et al*., 2002). Giomers are claimed to be fluoride rechargeable. This has yet to be validated by doing studies. Delivery of fluoride is accomplished by several means; most commonly, these include the use of fluoridation of public water supplies, supplements and the professional application of topical fluoride agents. Several concentrations can be used as topical fluoride (Stephen, 1994). In a study conducted by Freedman and Diefendefer (2003) on daily exposure of glass ionomer based restoratives to fluoride, they concluded that typical home care fluoride exposure provided adequate measurable fluoride uptake and subsequently release in these materials, with a higher level for resin modified glass ionomer. Acidic demineralizing solutions were more effective on fluoride release before fluoride recharging compared to neutral remineralyzing solution in this materials.

The aim of this study was to examine, the fluoride releasing and recharging ability of glass ionomer and resin based materials containing fluoridated glass filler and also comparing the recharging ability of these materials after exposure to topical fluoride.

MATERIALS AND METHODS

The materials tested in this study included 4 glass ionomer cements Fuji IX, Fuji VII, Fuji IX Extra, Fuji II LC, a Compomer (Dyract Extra) and a Giomer (Beautifil). The characteristics of the used materials in the study are given in Table 1.

Specimen preparation: A cylindrical aluminum mold (4 mm diameter and 8 mm Depth) used to prepare required samples. The materials prepared according to the manufacturer's instruction and packed into the molds. The specimens covered by a Mylar strip and glass slides and allowed to set at room temperature for 10 min in chemically curing materials. The light curing materials cured from top and bottom using a light source (Pencure, J Morita MFG. corp. Japan) for 40 sec. An additional 20 sec light was given in the middle of sample from both sides. Twenty samples (n = 20) of each material were prepared. Prior to testing, the specimens incubated in a 95% relative humidity environment at 37°C for 24 h. Then the specimens of each group (n = 20) immersed in 1 mL dionized water in polyethylene vials and stored in the incubator at 37°C.

The procedure repeated for 3 weeks daily and fluoride release measurement was made for the first 7 days and on the day 14 and 21.

A fluoride ion selective electrode (Ion Check 45, Radiometer analytical, France) used to measure fluoride release. The instrument calibrated according to manufacturer's instruction using 6 standard fluoride solutions containing 0.20, 1.00, 2.00, 10.00, 20.00 and 100 ppm F, respectively. Before measurement 0.1 mL of TISAB III was added to each solution to provide constant background ionic strength, decomplex fluoride and adjust PH and then concentration (ppm) of each sample solution recorded. The final results are reported as cumulative fluoride release ($\mu g\ cm^{-2}$) and daily fluoride release ($\mu g/cm^2$/day) in the results report.

Table 1: Materials used in the study

Product	Type	Manufacturer	Shade	Code
GC Fuji VII	GC GC	Corporation, Tokyo, Japan	Pink	FVII
GC Fuji IX GP Fast	GC GC	Corporation, Tokyo, Japan	A3	FIX
GC Fuji IX GP Extra	GC GC	Corporation, Tokyo, Japan	A3	FIX EX
GC Fuji II LC	GC GC	Corporation, Tokyo, Japan	A3	FII LC
Dyract Extra	RMGC	Densply Detrey GmbH, Germany	A3	DE
Beautifil	Giomer	Shofo dental corporation, USA	A3	BT
NeutraFluor 220	Mouthwash	Colgate, USA	Green	M
Total 12	Toothpaste	Colgate, USA	White	T

Fluoride release after recharge: Following 21 days of initial fluoride release, the samples divided into 2 groups each of 10 (n = 10). The samples of 1 group exposed to 220 ppm mouth wash solution for 2 min and then washed with copious deionized water for 10 sec and dried. The samples of other group, hand brushed using 1000 ppm F toothpaste for 2 min and then wiped clean with a tissue and rinsed for 10 sec using deionized copious water and dried.

Each sample returned to a new container filled with 1 mL, of fresh deionized water and storage media was changed daily for 1 week and fluoride release after recharge was measured and recorded daily for a total of 7 days.

The final results reported as fluoride release rate (μg/cm^2/day) taking into account the surface area and solution volume of each specimen using the following equation, where, 1.21 cm^2 is the surface area of the sample materials tested. The data analyzed using 2 ways ANOV A and Tukey Kramer multiple comparison tests.

In this study, topical fluoride application started from the 21st day, because the amount of fluoride release from most of the materials became similar at 21 days after immersion in water. Regarding fluoride exposure time to the materials, the rationale for this protocol is that most people expose their teeth to topical fluoride by brushing their teeth with a fluoride containing toothpaste or use a fluoride containing mouth rinse.

RESULTS

Analyzing the data showed that there was significant differences in fluoride release between different days and different materials and also in fluoride release before and after recharge between different days and materials. $p<0.05$.

On the 1st day of immersion FVII released, the maximum amount of fluoride, followed by FIX EX, FII LC, FIX, DE and BT in descending order. All the materials continued to release fluoride, but a higher increase in fluoride release was seen for materials compared to BT and DE after 7th day. DE and BT both released low amount of fluoride, but DE released more fluoride compared to BT on the 1st day, with significant difference and this difference continued for all the days of fluoride release. Fluoride released from FII LC compared to FIX on the 1st day was higher (Table 2).

On the 21st, the maximum fluoride release was related to FVII, followed by FII LC, FIX EX, FIX, DE and BT. The maximum fluoride release in samples treated by mouthwash released by FVII, followed by FIX EX, FII LC, DE, FIX and BT in descending order. In samples treated by toothpaste, the order of fluoride release on the 22nd day was as FVII>FII LC>FIX EX> FIX> DE>BT (Table 2).

The maximum fluoride uptake from mouthwash on the 22nd was related to DE and then FIX EX, maximum uptake from toothpaste related to FII Le.

The amount of fluoride released on the 21st day and on the 22nd day by mouthwash treated samples of FVII was not significantly different, but this difference for samples treated with toothpaste was significant.

For BT, DE, FIX, FII LC and FIX EX the amount of fluoride released on the 22nd after recharge by samples exposed to mouthwash or toothpaste was significantly >21st day. Also the amount of fluoride released on the 22nd, in samples treated by toothpaste was significantly greater than mouthwash treated one.

The difference between the amounts of fluoride released on the 22nd from samples treated by the 2 recharging agent in FVII, was not significantly different from each other.

The fluoride release from FVII decreased during the 7 days after recharging; so that the amount of fluoride released from specimens treated by mouthwash or toothpaste on 28th day was not significantly different form the values of 21st day. This condition also was observed for BT, FII LC, FIX EX and DE samples treated with mouthwash, but in samples of DE treated with toothpaste significant lower fluoride released on the 28th day compared to 21st day.

In samples of FIX treated by mouthwash or toothpaste, the amount of released fluoride on the 28th day was significantly yet higher compared to 21st day.

The difference between fluoride released from FII LC mouthwash treated samples on 21st and 22nd days, was less significant compare to BT, DE, FIX, FIX EX. For BT the release of fluoride gradually decreased, so that the

Table 2: Daily fluoride release and uptake from tested materials (μg/cm²/day). M represent mouthwash and T toothpaste. SD is given in parenthesis

Days	F VII	FIX	FIX EX	FII LC	DE	BT
D1	38.74 (6.83)	12.22 (1.26)	29.82 (3.84)	17.52 (5.00)	1.46 (0.25)	1.29 (0.17)
D2	23.45 (4.62)	5.72 (1.10)	11.81 (2.28)	8.87 (3.40)	0.63 (0.14)	0.99 (0.18)
D3	16.20 (3.86)	4.35 (0.74)	8.47 (1.44)	6.20 (2.07)	0.55 (0.16)	0.58 (0.14)
D4	12.72 (2.75)	4.34 (4.56)	7.51 (1.10)	5.19 (1.82)	0.45 (0.14)	0.47 (0.11)
D5	11.19 (2.66)	3.01 (0.50)	4.35 (0.73)	4.22 (1.41)	0.39 (0.11)	0.41 (0.09)
D6	9.70 (2.87)	2.29 (0.46)	3.57 (0.62)	3.66 (1.31)	0.41 (0.11)	0.41 (0.08)
D7	8.58 (1.90)	2.02 (0.46)	2.93 (0.44)	3.07 (1.27)	0.38 (0.12)	0.28 (0.06)
D14	4.62 (1.10)	1.31 (0.20)	2.38 (0.35)	2.57 (0.76)	0.45 (0.09)	0.29 (0.08)
D21	4.03 (0.97)	0.99 (0.19)	1.68 (0.29)	1.95 (0.49)	0.48 (0.09)	0.23 (0.07)
D22M	4.33 (1.08)	1.31 (0.12)	2.45 (0.37)	2.45 (0.69)	1.37 (0.18)	0.55 (0.16)
D23M	3.89 (1.16)	1.28 (0.15)	1.74 (0.23)	2.12 (0.32)	1.00 (0.12)	0.48 (0.24)
D24M	4.44 (1.15)	0.70 (0.13)	1.98 (0.25)	2.02 (0.18)	0.71 (0.10)	0.51 (0.17)
D25M	3.23 (0.91)	1.01 (0.17)	1.45 (0.21)	1.93 (0.27)	0.87 (0.16)	0.77 (0.23)
D26M	3.71 (1.04)	0.82 (0.12)	1.68 (0.28)	1.77 (0.21)	0.69 (0.09)	0.70 (0.23)
D27M	3.54 (0.96)	0.92 (0.23)	1.55 (0.19)	1.80 (0.23)	0.66 (0.10)	0.49 (0.21)
D28M	3.58 (0.86)	0.73 (0.15)	1.40 (0.23)	1.61 (0.28)	0.48 (0.09)	0.31 (0.14)
D22T	5.05 (0.89)	1.94 (0.12)	3.34 (0.50)	3.82 (1.27)	1.79 (0.28)	1.38 (0.23)
D23T	4.13 (0.87)	1.37 (0.16)	2.02 (0.25)	2.76 (0.85)	1.64 (0.27)	0.64 (0.08)
D24T	4.24 (0.87)	0.75 (0.08)	2.29 (0.28)	2.35 (0.58)	0.92 (0.12)	0.60 (0.14)
D25T	3.04 (0.81)	1.12 (0.10)	1.55 (0.20)	2.10 (0.60)	0.99 (0.25)	0.68 (0.12)
D26T	3.61 (0.66)	0.94 (0.16)	1.91 (0.21)	1.94 (0.53)	0.96 (0.16)	0.59 (0.13)
D27T	3.33 (0.70)	1.06 (0.14)	1.82 (0.18)	1.99 (0.52)	0.85 (0.12)	0.55 (0.17)
D28T	3.35 (0.61)	0.70 (0.13)	1.50 (0.21)	1.74 (0.45)	0.89 (0.05)	0.31 (0.09)

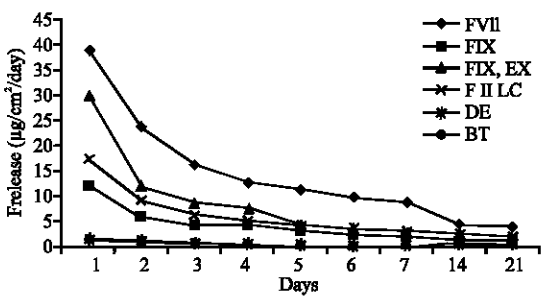

Fig. 1: Daily fluoride release from tested materials

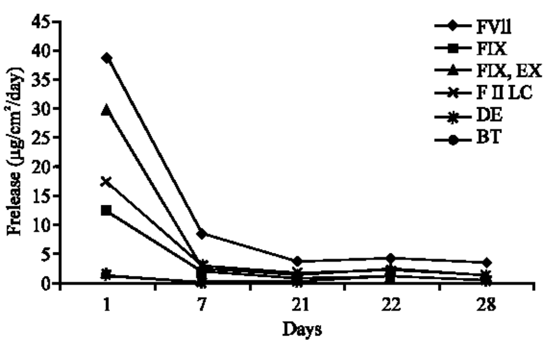

Fig. 2: Fluoride release from tested materials after recharge by mouthwash

amount of released fluoride on the 28th day was not significantly different from the 21st day. On the 28th day, the amount of fluoride released from samples treated by toothpaste or mouthwash was not significantly different from each other Fig. 1-3.

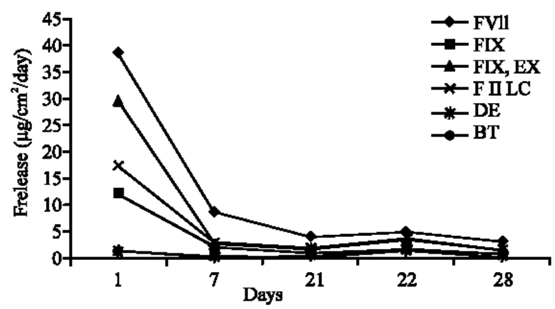

Fig. 3: Fluoride release from tested materials after recharge by toothpaste

DISCUSSION

The content of fluoride in restorative materials should, however, be as high as possible without adverse effects on physico mechanical properties and the release also should be as great as possible without undue degradation of the filling.

An initial fluoride burst effect is desirable, as it will reduce the viability of bacteria that may have been left in the inner carious dentin and induce enamel/dentin remineralization (Forsten, 1998). High level of fluoride release on the 1st day may be caused by the initial superficial rinsing effect, while the constant fluoride release during the following days occurs because of fluoride ability to diffuse through cement pores and fractures.

Fuji VII released highest rate of fluoride compared to another tested materials in this study, which can be in the same direction purpose of designing this material. The different chemical and physical characteristics of F VII and F IX may be responsible for their difference in fluoride release.

Low fluoride release in F IX is attributed to glass filler content with fewer monovalent ions cross linking the polymer chains holding them close together, leading. To less water transport and consequently less fluoride release (Rothwell *et al*., 1998). The results of this study about Fuji VII and F IX, is in accordance with the another study results (Gandolfi *et al*., 2006).

It is important to consider that different methodology used in the studies, including specimen size, media used to measure fluoride release and uptake, quantity of media used to measure fluoride and different methods to measure fluoride release, are responsible for the high numerical differences found among studies.

The highest values of fluoride release after Fuji VII, was related to Fuji IX extra, which can be related to incorporation higher fluoride compounds compared to Fuji IX glass ionomer.

Tay *et al*. (2001) found, a thinner hydrogel layer in FII LC compared to thicker 300 nm, silica gel layer in Chem Flex (conventional glas ionomer) that became thicker upon water sorption and can be case for changing in trend of fluoride release in FII L after 1st week of immersion. A very thin hydrogel layer in Dyract AP and no appreciable change occurred in reactamer paste by water storage.

Higher amount of fluoride release for FII LC compared to F IX on the 1st day of immersion is in accordance with the results of fluoride released by resin modified and conventional glass ionomers in another study, Rothwell *et al*. (1998), which can be primarily due to ion exchange, but a degree of wash-out or dissolution may also contribute to the this higher fluoride release.

Initial setting of resin modified glass ionomers is performed by light activated polymerization followed by an acid base reaction arises from sorption of water. Resin modified glass ionomers were mostly found to have a potential for fluoride release in equivalent amounts as conventional cements, but may be affected not only by the formation of complex fluoride compounds and their interaction, but also by the type and amount of resin used for the photochemical polymerization reaction (Wiegand *et al*., 2007; Forsten, 1995). Beautifil showed little amount of controlled fluoride release in study. Beautifil contains Surface Pre Reacted Glass ionomer (S-PRG) as a fluoride component. The fluoride glass within beautifil has little or no glass ionomer matrix phase, because of the lack of any significant acid base reaction. As PGR has been pre reacted with fluoroaluminosilicate glass and acid, water sorption is not critical in the acid base reaction as is seen in this study and is in agree with results of other studis (Yap *et al*., 2002; Itota *et al*., 2004b).

Another explanation for highly difference in fluoride release between GICs and resin composites like (Compomers and Giomers) is that obviously the porosity of the materials may have a great influence on the amount of fluoride release. These materials, have added resin content compared to GICs, the barrier through, which water and fluoride to diffuse also increases, in addition to their filler solubility differences (Xu and Burgess, 2003).

Dyract extra also showed a low diffusion controlled fluoride release. Although, dyract includes a fluoride containing acid degradable glass and an acidic species capable of reacting with glass, there is no water present in the material to facilitate acid base reaction. If the reaction does occur, it is due to the diffusion controlled uptake of water by the cement from the surroundings.

Dyract extra based on manufacturer information contains strontium fluoride, but it seems that incorporating this composition does not lead to much fluoride release from Dyract extra compared to Dyract (Weidlich *et al*., 2000). With regard to compomers, differences in fluoride release is found in products with different filler systems (Wiegand *et al*., 2007). However, the difference between glass ionomers and compomers during the 1st weeks of immersion could be due to the fact that after curing and before contact with water the fluoride in polyacid modified composite is not free, but bound in the filler particles, which are enclosed in the polymerized matrix and in the 1st phase of setting, polyacid modified composite resin completely behave like composites.

The amount of fluoride release from tested materials, on the 1st day of re-release was significantly different. Xu and Burgess (2003) suggested that material with higher fluoride release has a higher fluoride recharging ability. Itota *et al*. (2004b) found that the tendency for the amount of fluoride re-release following recharging to increase with the age of specimen and this tendency is inversely proportional to the amount of fluoride previously released from the specimen. Therefore, it seems likely that fluoride taken up after recharging occupies the sites, which have been previously occupied, by fluoride before it is released. Accordingly, the amount of fluoride recharge may have a limit, which depends upon the inherent fluoride releasing ability of each material, because the sites occupied by intrinsic fluoride are fixed and limitative within the materials.

Higher porosity will allow deeper diffusion of the recharge agent into the sample, leading to a higher amount of fluoride storage and release.

A study suggests that behavior of all brands of one class of material, cannot assumed by studying one representative of each class. The permeability of each class is likely to be a major factor in the mechanism of fluoride recharge and is also likely to be the factor that may account for differences between the materials (Preston *et al*., 2003).

Both recharging agents used in this study, could recharge BT samples. The higher fluoride released on the 22nd day from samples recharged by toothpaste, compared to mouthwash be because of high viscosity and sticky nature of the toothpaste, which was difficult to wash off, may have remained trapped in pores in the specimens to release more fluoride on the 1st day of after recharge immersion. Higher concentration of fluoride in toothpaste (1000 ppm) compared to mouthwash, chemical nature of the toothpaste and scrubbing effect of brushing that has incorporated higher amount of fluoride into the sample surface can be other cases for this difference (Gao *et al*., 2000). Capability of the Giomers to recharging can be attributed to the well established glass ionomer matrix around glass filler particles (Itota *et al*., 2004a).

The results about beautifil recharging capability is corroborated by the results of another study (Okuyama *et al*., 2006).

The uptake of fluoride by DE following fluoride treatment in this study is in accordance with the results of other study about Dyract AP (Cildir and Sandalli, 2005).

It is believed by Itota *et al*. (2004b) in their study that the extent of the glass ionomer matrix layer in Dyract AP was insufficient to influence the recharging of the material and the recharging ability of this kind of materials is thought to depend on the absorption and diffusion effects within the resin matrix and by the presence of porosity. Also the disintegration of the matrix regions around glass fillers caused by sodium fluoride solution may result in enhancement of the fluoride recharge ability of the material (Itota *et al*., 2004a). FVII in our study did not replenish with mouthwash, which can be because of low concentration of fluoride or insufficient exposure time to mouthwash, or indicating that FVII can't not replenish by applied mouthwash. A longer storage time before recharging may lead to more exhausting the FVII from fluoride content and promote its uptake.

Higher fluoride release on 22nd day in toothpaste treated samples compare to mouthwash treated samples can be following entrapment of sticky paste in superficial pores and its release on the 1st day of re-release of fluoride. The results of this study about recharging effect of NaF on FVII is in agree with Gandolfi *et al*. (2006) results. They stored samples in storage media with different PH and found no significant F absorption following fluoride treatment by the Samples stored in media with PH equal to 5 (Double deionized water) (Gandolfi *et al*., 2006).

The samples of FIX exposed to mouthwash and toothpaste showed re-release on the 22nd day, although, not very higher than 21 SI day, but significantly different, which is in agree with other study results (Weidlich *et al*., 2000; Cildir and Sandalli, 2005; Hsu *et al*., 2004; Rothwell *et al*., 1998; Xu and Burgess, 2003; Forsten, 1998).

Sample of FII LC could uptake fluoride from recharging agents, with lesser amount of fluoride uptake from mouthwash. FII LC also released significantly higher fluoride on the 22nd day compared to 21st day that shows RMGI materials can replenish by recharging agents as is indicated in the other studies (Preston *et al*., 1999; Dunne *et al*., 1996; Freedman and Diefenderfer, 2003; Rothwell *et al*., 1998; Forsten, 1998).

All the materials tested in this study could uptake fluoride by applied recharging agents, except FVII, which could not uptake fluoride from mouthwash solution, but it is important to consider that different methodology used in the studies like, specimen size, media used to measure fluoride release and uptake, quantity of media used to measure fluoride, different methods to measure fluoride release, number of recharging exposures, acidity of recharging agent, duration time of exposure, concentration of fluoride in recharging agent are responsible for the high numerical differences found among studies. Thus, comparison must be made considering behaviour of materials rather than the absolute amount of fluoride release and uptake (Freedman and Diefenderfer, 2003; Gandolfi *et al*., 2006; Itota *et al*., 2004b; Gao and Smales, 2001b; Okuyama *et al*., 2006).

Finally, a slow release of fluoride from dental materials may have clinical implications *in vivo*. Fluoride release from GICs restorations increases the fluoride concentration in saliva and in adjacent hard dental tissues. Thus, continuous small amounts of fluoride surrounding the teeth decreases demineralization of the tooth tissues although, it is not proven by prospective clinical studies whether the incidence of secondary caries can be significantly reduced by the fluoride release of restorative materials (Wiegand *et al*., 2007). Cate *et al*. (1998) deduced that dentin demineralization was inhibited in a clinically relevant percentage only at fluoride levels above 1 ppm. Near optimum fluoride effects can be achieved with quite low concentrations in a daily fluoride rinse (Featherstone *et al*., 1990). The effect of a very low amount of continuous fluoride release from Giomers and compomers on dental hard tissues is needed to be further studied. Restorative materials with a high fluoride release generally have lower mechanical properties. Therefore, they may not be as durable clinically as lower fluoride releasing materials, particularly in load bearing areas (Xu and Burgess, 2003). Mechanically stronger materials, usually release only a small amount of fluoride. Therefore, frequent external application of fluoride is necessary to maintain the high fluoride release and provide caries protection.

CONCLUSION

It seems that the extent of the glass ionomer matrix plays an important part in determining the fluoride recharging ability of GICs materials. The fluoride recharging ability of the materials will become an important factor for selection of a material for clinical use, because in the long term the fluoride release through the recharging route is significantly greater than that release from within the materials.

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