Original Article

An In-Vitro Study on the Release of Fluoride from Two Restorative Materials and Their Rechargeability after Exposure to Daily 1000 ppm Fluoride

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Abstract:

Statement of Problem: Since the fluoride releases from materials with the property of releasing fluoride are decreasing gradually, it seems that probably the material rechargeability is more important than their long-term fluoride release.

Purpose: the objective of this study was to asses the fluoride release and rechargeability of 2 types of fluoride releasing restorative materials, a resin modified glass ionomer (Vitremer) and a compomer (Compoglass F), after exposure to daily NaF solutions containing 1000 ppm F, for 1 minute.

Materials and Methods: Twelve discs (8 mm ×2 mm) of each of the materials were fabricated, and divided into 2 groups (test and control). All discs were stored in 4 mL artificial saliva at 37°C. In group 1 (N=6), the specimens were immersed in artificial saliva which was changed daily for 25 days. In group 2 (N=6), in addition to receiving the same treatment as group 1, the specimens were immersed in NaF solution (1000ppm F, ph=6.9) for 1 minute before daily saliva change. A potentiometer was used to determine the amount of fluoride released on days 1, 2, 3, 5, 10, 15, 20 and 25, after the daily saliva change, in all study groups. Data were analyzed by the *t*-student test after confirmation of the equality of variances by Leven's test.

Results: Both materials continued releasing fluoride throughout the whole study period. For each material, the release was highest on day one. During the first 3 days, glass ionomer released significantly higher amounts of fluoride as compared to compomer ($p<0.05$); but afterwards, there was no significant difference between the 2 materials ($p>0.05$). After exposure to NaF solution, none of the materials showed statistically significant rechargeability ($p>0.05$) and the amount of fluoride-release continued to drop during the study period in similar patterns for both the test and the control groups.

Conclusion: It may be concluded that rechargeability of glass ionomer and compomer, using daily neutral fluoride mouth rinses and toothpastes does not occur in reliable amounts.

Key Words: Fluoride release; Fluoride uptake; Resin modified glass ionomer; Compomers

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INTRODUCTION

The effect of systemic and topical fluoride (F) on prevention of dental caries has been demonstrated. Various restorative materials with the ability to release fluoride are made for the purpose of caries prevention and enhancement of the duration of enamel exposure to fluoride. A source of fluoride release that discharges fluoride in low but continuous levels, can highly aid in the prevention of dental caries and the decrease of secondary caries [1,2].

The glass ionomer (GI) restorative materials have received considerable attention, because of their prolonged fluoride-releasing capacity. Conventional glass ionomers are rarely used in pediatric dentistry, due to the difficulties in their clinical application, poor mechanical properties, low wear resistance and technical sensitivity. On the other hand, resin modified glass ionomer cements (RMGIC) and compomers (Poly Acid Modified Composite Resin;PAMCR) are drawing more attention, every day [3,4].

Various investigations have shown that most fluoride releasing materials, primarily release fluoride in large amounts, which decrease rapidly, and reach a constant and low level (2,5-7). Since fluoride release continues in low amounts, it may be postulated that its anti-caries effect is gradually eliminated.

Several reports have indicated that these materials are capable of being recharged by some type of topical fluoride and can act as rechargeable sources of F and resources of fluoride storage (2,5-8).

In most studies, fluoride released from specific materials is measured in a period of time, and after the release drops to lower levels, the samples are exposed to topical fluoride. The concentration and period of exposure usually does not correlate with that of natural conditions.

RMGICs and compomers are restorative materials used in pediatric dentistry with the ability to release fluoride. The present study was designed to determine and compare the amount and pattern of F release from these materials in two conditions: 1) no exposure to fluoride, and 2) daily exposure to 1000ppm fluoride. This method largely simulates the dynamic procedure of fluoride release and uptake in the oral environment. However further studies should be performed before the material can be recommended as a rechargeable source of fluoride for the prevention or control of caries..

MATERIALS AND METHODS

In this experimental study, two types of fluoride-releasing restorative materials were used (Table I). Twelve discs, 8mm in diameter and 2mm in height, were made from each material in prefabricated celluloid molds, according to the manufacturer's instructions. The samples were cured from both sides of the molds and were then immersed in a plastic plate containing 4 mL artificial saliva (20 mM $NaHCO_3$, 3mM NaH_2PO_4, 1 mM $CaCl_2$ with the pH=7) and were finally stored in a 37°C incubator for 24 hours. After 24 h, 6 specimens of each material were removed from the artificial saliva and were dried on filtration paper for 2 minutes. Afterwards, each specimen was exposed to 5mL Naf solution (Naf 0.2%, 1000 ppm F, PH=6.9, Department of Chemistry, Science Faculty, Tehran University) for one minute. Specimens were again dried and stored in a new 4mL soloution of artificial saliva in the 37°C incubator for

Table1-The restorative materials used in this study

Group	Type of material	Commercial name	Curing system	Manufacturer
1	RMGIC	Vitremer	Tricure	3M Dental Product, St. Paul, MN, USA
2	PAMCR	CompoglassF	Light Cure	Ivoclar Vivadent AG, Liechtenstein

another 24 h. The other 6 specimens were used as the control group and were subjected to the same procedure, except that they were not immersed in a fluoride solution. This process was repeated every 24 hours at an exact time for 25 days. In each group, the amount of fluoride release in the artificial saliva was determined on days 1, 2, 3, 5, 10, 15, 20 and 25 by a potentiometer.
The data were analyzed using the *t*-student test after confirmation of the equality of variances by Leven's test.

RESULTS

Table II demonstrates the amount of fluoride released from the evaluated materials in two different situations of no charging and recharging with daily 1000-ppm fluoride on days 1, 2, 3, 5, 10, 15, 20 and 25.
In the first situation, Vitremer showed the highest amount of fluoride release on day 1 (29.83 ppm), which dropped rapidly on the second day, reaching 8.97 ppm. Fluoride release continued to decrease gradually during the entire period, dropping to 1.24 ppm on the 25th day.
Compoglass F also demonstrated the highest amount of release on the first day (4.63 ppm) and decreased gradually during the study period, finally releasing 1.46 ppm F on day 25. The decrease in Compoglass F was more uniform, as compared to Vitremer at the initiative intervals of the study.
A significant difference in fluoride release was observed on the first 3 days, between the 2 studied materials in both experiment setups ($p<0.05$); however, this difference was not significant for the rest of the studied intervals ($p>0.05$).
Statistically significant rechargeability behavior was not identified in either of the studied materials ($p>0.05$). Fluoride release continued to decrease in both test groups, in spite of being stored in the daily recharging solution.

DISCUSSION

Both materials used in this study release fluoride, and the highest amount of this release occurs on the first day, with a gradual decrease thereafter. The resin modified glass ionomer, Vitremer, released more fluoride on the first day (29.83 ppm) which remarkably decreased on the second day, dropping to 8.97 ppm. Similar findings were reported by other investigators for conventional and resin modified glass ionomers. This could be related to the presence of acid-base reaction in these materials [9].
The type and amount of resin, used in the hybrid structure of ionomers may affect their fluoride-releasing property and provide a difference among the various materials in this group. This may be due to the fact that resins

Table II: Amount of fluoride release (ppm) from evaluated specimens

Material	Setup	Number	Days of measeerment							
			1	2	3	5	10	15	20	25
RMGI	1*	6	29.83 (4.94)	8.97 (2.10)	839 (3.22)	3.53 (1.26)	2.58 (0.21)	1.92 (0.39)	1.48 (0.30)	1.24 (0.36)
	2**	6	30.33 (8.11)	11.53 (3.3)	10.67 (4.1)	4.18 (1.84)	2.78 (0.92)	2.76 (1.28)	1.51 (0.38)	1.54 (0.25)
Compomer	1*	6	4.63 (1.63)	4.14 (1.64)	3.73 (1.72)	2.47 (0.39)	2.09 (0.56)	1.92 (0.42)	1.56 (0.32)	1.46 (0.39)
	2**	6	6.00 (0.97	4.82 (2.56)	3.71 (1.44)	3.25 (1.24)	2.10 (0.98)	2.17 (0.86)	1.82 (1.0)	1.55 (0.61)

* No charge, ** Rechargeability condition; contact with 1000 ppm F solution daily For 1 minute
Values are mean (standard deviation)

cover fluoride ions and have an effect on the penetrability and solubility of these materials. With regard to compomers, since no immediate acid-base reaction occurs in these materials, the amount of fluoride release is in a low level at the beginning of the study. Fluoride is only released from the glass, that is present in compomers, and fluoride-release decreases gradually and slowly [9-11].In the present study, the difference in the release of fluoride between the two materials was only significant in the first 3 days. This difference decreased gradually during the following days. There was no significant difference between the amounts of released fluoride from the two materials after the third to the 25^{th} day, but both materials continued releasing fluoride throughout the entire period of the study. On day 25, the control subgroups of the Vitremer and Compoglass F groups, released fluoride 1.24ppm and 1.46ppm respectively. Therefore, both of these materials can be recommended as fluoride releasing materials in individuals prone to caries. It should be noted that there is still no agreement on the minimal amount of fluoride that needs to be released from restorative materials in order to inhibit caries. Various studies on this subject represent contrary results [1,12-14].

Considering the gradual decrease observed in the amount of fluoride released from different materials, it has been proposed that these materials must have the ability to be recharged in order to provide the fluoride levels required for re-mineralization of tooth structures [6,15]. Most of the studies investigating the rechargeability of fluoride-releasing restorative materials have employed gels or solutions containing large amounts of fluoride that are not usually used routinely and often have professional usage. Undoubtedly, the most common form of topical fluoride used by most individuals is the application of fluoridated toothpaste at least once a day. Toothpastes available in the market were not used in this study, because of the differences in their formulations. In addition a possibility also exists that some of the substances present in toothpastes, react with fluoridated compounds and decrease the fluoride bioavailability [16]. Since 1000 ppm F sodium fluoride is the most common form of fluoride in new toothpastes and mouth rinses, a NaF solution containing 1000 ppm F was used as a recharging agent in the present study [15].

Some reports indicate that the use of fluoride-containing gels on old specimens of glass ionomers, causes fluoride release from the material, but it has been shown that if the gel has acidic properties, the surface of the restorative material would eventually be destroyed and plaque accumulation on the material surface would result. Thus, it is recommended to use neutral recharging agents [17-19]. The pH of the NaF solution utilized in this study was in a neutral range (pH = 6.9).

Neither the RMGIC nor the compomer used in the present investigation, showed statistically significant rechargeability. The mechanism of fluoride ion release after the application of different fluoride recharging agents is still not clear; it may depend on several factors such as material penetrability, the viscosity and form of the recharging agent, the concentration of fluoride used for the purpose of recharging, and the pH of the recharging agent [1,5].

The factor which makes materials different with regard to rechargeabilty is probably the material's penetrability that affects the depth of fluoride release and uptake [15].

Creanor et al. [5] investigated the fluoride-releasing characteristics of conventional GIs and a type of light-curing glass ionomer. They demonstrated that these materials had the ability to be recharged when exposed to fluoride. All specimens used in this study were aged in distilled water for 2 months before exposure to recharging solutions in order to discharge a large amount of the fluoride out of the specimens. This procedure may increase the material's reaction for the purpose of refilling with fluoride. In order to simulate the oral environment as much as possible, the specimens used as the test group in the current study, were exposed to daily 1000ppm F for 1 minute without being aged for long periods of time and were then compared with the control group.

Another factor that may affect the rechargeability of GIs is the concentration of fluoride present in the recharging agent; higher concentrations of fluoride in recharging agents can increase the rechargeability rate [2,20]. This study used a concentration similar to that of normal daily toothpastes.

In addition to the concentration of fluoride in the recharging agent, its form and viscosity may be an important factor. It has been shown that a greater amount of fluoride is released after exposure to a 2% NaF gel as compared to a 2% NaF solution [21].

Rechargeability has been reported in studies using APF gel as a recharging agent [17,19,22]. However, Gao et al [23] stated that due to the high viscosity of the APF gel, it may have been trapped in the pores and cracks of the specimens; eventually releasing fluoride ions as the gel dissolves in the artificial saliva which it was placed in. The study of Beligin et al [17] also demonstrated that the specimens exposed to daily 2% APF gel, released more fluoride than the specimens exposed to the same amount of 2% NaF solution. Gao et al [25] believed APF gel to cause surface damage in all materials especially conventional GIs, therefore the increase that was observed in fluoride release, was assumed to be related to surface damage of the fluoridated restorative materials and not to a true chemical recharging. In the present study, NaF was used in the form of a solution in order to decrease the probability of cross contamination, caused by the viscosity of the recharging agent.

Another influential factor may be the pH of fluoride-recharging agents. Rashidian [24] showed that the amount of fluoride-release increases with the use of the acidic solution of 2% NaF in comparison to the neutral solution of 2% NaF. The NaF solution (1000 ppm F, neutral pH) which was used in this study may be responsible for the lack of a statistically significant increase in fluoride release.

Although studies such as those conducted by Creanor [5], Hatibovic Kofman [2], and Rothwell [7] confirm the recharging phenomenon, it is obvious that charging effects remain active only for a very short period of time. Creanor et al [5] used a solution of 1000 ppm NaF and showed the amount of fluoride release decreased 2 hrs after recharging. Rothwell et al [7] after exposure of their specimens to 10 ml toothpaste containing NaF for an hour, observed that the highest amount of fluoride-release occurred a day after exposure to the charging agents and its effect diminished after 3 days. Gao et al [23] also observed the charging effect to exist for a short period of time. Thus, it seems that the recharging phenomenon which is confirmed in several studies may only be a surface effect or a cross contamination.

The exact mechanism of recharging is not yet clear. Various studies represent different theories, such as erosion of the material in the presence of a low pH, the washing-out of the remnants of a viscous gel from the porosities of the material, or by subsequent diffusion of fluoride ions taken up by the matrix of the restorative materials [23].

CONCLUSION

In this study, it was concluded that the rechargeability of Vitremer and Compoglass F, through common neutral fluoride solutions is not possible. Of course further studies are necessary to confirm these results. Therefore, it is suggested that other methods such as diet control, plaque control, use of fluoride (either home or professional)… also be considered for the prevention and control of caries. Application of mouth rinses and daily fluoride gels, fluoride varnishes with the ability of periodic use, fluoridated chewing gums and dental flosses could be beneficial in order to provide continuous fluoride release in the mouth.

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بررسی In-vitro میزان رهاسازی فلوراید از دو ماده ترمیمی و قابلیت شارژ مجدد آنها پس از قرارگیری در معرض ۱۰۰۰PPM فلوراید روزانه

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چکیده

بیان مسأله: میزان فلوراید رهاشده از مواد ترمیمی در اثر مرور زمان کاهش می‌یابد و قابلیت شارژ مجدد آنها توسط منابع خارج دهـانی از اهمیت خاصی برخوردار است.

هدف: مطالعه حاضر با هدف تعیین میزان رهاسازی فلوراید از دو ماده ترمیمی گلاس‌آینومر تغییر یافته با رزین (Vitremer) و کـامپومر (Compoglass F) پس از قرار گرفتن در معرض ۱۰۰۰PPM سدیم فلوراید به مدت یک دقیقه در روز انجام شد.

روش تحقیق: تعداد ۱۲ دیسک به ابعاد ۲×۸ میلیمتر از هر کدام از مواد ساخته شد و به دو گروه مساوی تقسیم شـدند. از نمونـه‌هـا در ۴ میلی‌لیتر بزاق مصنوعی و در دمای ۳۷ درجه سانتیگراد نگهداری شد. در گروه اول نمونه‌ها در محیط بزاق مصنوعی بـه مـدت ۲۵ روز قرار گرفتند و بزاق مصنوعی روزانه تعویض می‌شد. در گروه دوم، هنگام تعـویض روزانـه محـیط و قبـل از قرارگیـری در محـیط جدیـد، نمونه‌ها در داخل محلول حاوی ۱۰۰۰PPM سدیم فلوراید با pH = ۶/۹ به مدت یک دقیقه غوطه‌ور می‌شدند. با اسـتفاده از پتانـسیومتر، میزان فلوراید آزاد شده در محیط، در هر گروه در روزهای ۱، ۲، ۳، ۵، ۱۰، ۱۵، ۲۰ و ۲۵ اندازه‌گیری شـد. نتـایج پـس از تأییـد یکـسانی واریانس‌ها (با استفاده از آزمون Leven's) توسط آزمون t نمونه‌های مستقل مورد ارزیابی قرار گرفتند.

یافته‌ها: هر دو ماده در طی مدت تحقیق از خود فلوراید رها کردند و در هـر دو مـاده روز اول بیـشترین میـزان فلورایـد آزاد شـده بـود. گلاس‌آینومر نسبت به کامپومر در سه روز اول میزان بیشتری فلوراید آزاد کرده بود (P<۰/۰۵)، اما پس از آن اختلاف معنی‌داری بـین دو گروه مشاهده نشد (P>۰/۰۵). در گروهی که در معرض سدیم فلوراید قرار گرفته بود، هیچ کدام از دو ماده قابلیت شارژ مجدد معنی‌داری نشان ندادند (P>۰/۰۵) و میزان کاهش آزادسازی فلوراید در گروههای مختلف شبیه هم بود.

نتیجه‌گیری: مطالعه حاضر نشانگر این مطلب است که احتمالاً کامپومرها و گلاس‌آینومرهای تغییر یافته با رزین، زمانی کـه در معـرض دهانشویه‌ها و خمیردندانهای حاوی فلوراید قرار می‌گیرند، قابلیت شارژ مجدد زیادی پیدا نمی‌کنند.

واژه‌های کلیدی: رهاسازی فلوراید؛ جذب فلوراید؛ گلاس‌آینومر با رزین تغییر یافته؛ کامپومر

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