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Effects of Surface Pre-Reacted Glass Particles on Fluoride Release of Dental Restorative Materials

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Absract: *Objectives:* The objective of this study was to evaluate the effects of added surface pre-reacted glass particles on fluoride release pattern of dental restorative materials. *Methods:* Six disk shape samples (6x2 mm) of each material were prepared using standard moulds. Cured samples were removed from the moulds carefully and were incubated at 37°C for 24 hours in airtight containers. All samples were incubated at 37°C in 15 ml of de-ionized water. Fluoride release was measured using Ion Selective Electrode (Thermo-Orion Ionplus) for up to 28 days. Fluoride concentration in standard solutions and elution media was measured and calculated as parts per million (PPM). The data was analyzed statistically using 2 way ANOVA. *Results:* Two distinct stages of fluoride release, initial burst fluoride and later sustained release were observed in all materials. For Fuji II™ LC, release significantly higher amount of fluoride in to the elution media during any day compared to Beautiful. Sustained fluoride release was observed in both materials up to 28 days. *Conclusions:* Both materials (Beautifil® and Fuji II™ LC) used in this study showed the similar pattern of fluoride release, i.e. first initial burst release of fluoride followed by sustained release of fluoride for four weeks.

Key words: Glass ionomers · Giomers · Beautifil® · Pre-reacted glass particles · Fuji II LC

INTRODUCTION

The beneficial role of fluoride for oral and dental health is well documented and cannot be denied. Considering the vital role of fluoride; It has been focus of interest for researchers and scientists for many years. Till to date, a plenty of research has been conducted to analyze fluoride release pattern modifying physical conditions, chemistry and composition of fluoride releasing materials. A large number of restorative materials such as glass silicates, compomers, composites and giomers supplied by different manufacturers are available in the market; however differ widely from each other in terms of their properties and fluoride release [1].

Among fluoride releasing materials, the glass ionomers or glass silicate materials are the most popular in the literature found with search keyword "fluoride". Glass ionomers are being used widely because of their good properties such as bonding to tooth structure, biocompatibility and of course fluoride release [2]. On the other hand, there are a number of shortcomings for this group of materials, such as, poor aesthetic, prolonged setting reaction [3, 4], compromised mechanical properties [3] and weaker bond strength [5]. These shortcomings have been addressed by the addition of cellulose fibers [6], nanoparticles [7] including hydroxyapatite and fluoroapatite to glass ionomers [8]. In clinical perspective, it is crucial that any modifications in the material to improve physical and/or mechanical properties must not compromise the fluoride release properties [9]. The key benefits from fluoride release in the oral cavity are prevention of caries by decreasing the demineralization and increasing the remineralization of dental hard tissue as well as inhibiting growth of the microbial flora [10]. The amount of fluoride released is important to achieve this antibacterial and cariostatic effects [1]. Hence, the fluoride release should not be reduced while improving physical properties or strength of these materials. The fluoride elution is not a straight forward process and can be affected by a variety of factors; such as, composition and fillers [11], storage media composition and flow, pH of oral cavity and plaque

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Table 1: Materials used and description

	Material	Type	Composition	Manufacturer
1	Beautifil®	Giomer	S-PRG fillers, Glass fillers, catalyst, Bis-GMA/TEGDMA	Shofu Inc, Kyoto, Japan.
2	Fuji II™ LC Capsule	Resin Modified light cured glass-ionomer	Glass fillers, Radio opacers	GC Corporation Tokyo, Japan

formation [12-14], powder-liquid ratio, curing time and exposed surface area [12, 13]. For any newly developed material or new modification in an existing material where manufacturer claiming for the improvement of physical or mechanical properties, it is necessary to characterize it for fluoride release properties.

Giomers are relatively a new material developed in an attempt to improve the physical, mechanical and aesthetic properties. These are hybrid materials manufactured by adding pre-reacted glass filler particles (pre reacted treatment with acid before blending them) in the resin matrix. Manufacturer of these material have claimed to show better physical and mechanical properties [15]. In addition, giomers possess better aesthetic properties and ease of polishabaility [16].

There is little published research available in literature about Giomers in particular related to chemical and fluoride release properties. Hence, giomers are potential candidates to study fluoride release behavior and compare with established materials. The objective of this study was to evaluate the effect of added surface pre-reacted glass particles (S-PRG) on fluoride release and to compare it to resin modified glass ionomers. For this purpose, fluoride elution pattern was compared for Beautifil® ™ (S-PRG) and Fuji II™ LC (Resin modified glass ionomers).

Experimental Procedure

Materials: Two tooth coloured fluoride releasing restorative materials were used in this study. A giomer material (Beautifil®) containing surface pre-reacted glass (S-PRG) fillers and a resin modified glass ionomer material (Fuji II™ LC capsule assisted).

Both materials are dual cure; setting reaction is based on acid-base and photo-activation. The description of materials used is given in Table 1.

Methods

Sample Preparation: Six disk shape samples (6 mm x 2 mm) of each material were prepared using standard moulds made from polysulphide impression material. Manufacturer's instructions were followed for using all materials. For resin modified glass ionomer (Fuji II™ LC Capsule), a single capsule was activated by pushing capsule activation bar and amalgamated for 10 seconds using an amalgamator. A homogeneous glass material was poured from capsule into mould using a plunger. One capsule was used to make one sample only. The giomer material (Beautifil®) was available in ready to use paste form eliminating the need for mixing. The Beautifil® material was simply extruded from the tube and condensed in the moulds. The excess material was removed and surface of each filled mould was covered by a Mylar strip. All samples were cured following the manufacturer's directions using visible light. Prepared samples were isolated from the molds carefully to be inspected to rule out the presence of any voids or visible defect. All samples were incubated at 37°C for 24 hours in airtight containers in dry conditions.

All samples were stored in polypropylene containers and filled with 15 ml of de-ionized water. The incubation temperature (at 37°C) and pH (in the range of 6.4-7.1) was maintained throughout the experiments. Fluoride release from each elution was measured using Ion Selective Electrode (ISE) supplied by Thermo-Orion (Model Ionplus, 96-09BN). Electrode hand piece was cleansed using de-ionized distilled water prior to each measurement. The electrode was filled with Orion Ionplus® electrode solution (Thermo Orion). The electrode was calibrated using sodium fluoride (Orion) 0.1 M standard solution. A range of sodium fluoride solutions (0.001mM, 0.01mM, 0.1mM, 1.0mM and 10mM) was prepared using the standard solution. Calibration of ISE was performed before every measurement.

Fluoride release was measured after 24 hours followed by 3, 7, 14, 21 and 28 days. In order to get constant background ionic strength and de-complex fluoride, 100 µl of TISAB III was added to each solution before measurement. The TISAB III is used to de-complex fluoride and release all fluoride in the solution in ionic form. After the fluoride measurement, each specimen was transferred from its old container to a new container with 15 ml of fresh de-ionized water. Three readings for each sample were recorded to calculate the mean value. De-ionized distilled water at 37°C was used as blank for fluoride measurements control. Fluoride concentration in standard solutions and elution media was measured using calibrated ion selective electrode and calculated as parts per million (PPM) for comparison. The data was analyzed statistically using 2 way ANOVA; a value of $P<0.05$ was considered statistically significant.

RESULTS

The amount of fluoride released from each material was observed for 28 days (Fig.1). The amount of fluoride in blanks (de-ionized distilled water samples) was negligibly low confirming that no interference with fluoride release from the experimental materials. Burst release of fluoride is a unique property of fluoride releasing glass materials. It was exhibited in both materials Fuji II™ LC and Beautifil® and a significant amount of fluoride was released initially followed by a rapid decrease after three days. For Fuji II™ LC, the maximum fluoride release was recorded on day three (4.47±0.39 PPM where n=6) followed by day 7 (3.01±0.26 PPM where n=6). After a week, the amount of fluoride was dropped sharply to 1.9±0.087 PPM and maintained up to 1.68 PPM until day 28. The Beautifil® material containing surface pre-reacted glass (S-PRG) particles was observed to release significantly lower amount of fluoride in the elution media throughout the period of this study.

There was burst fluoride release from Beautifil®; 1.40±0.025 and 1.30±0.034 PPM (n=6) for day 1 and day 3 respectively (Fig 1) and that is significantly lower than Fuji II™ LC ($p<0.05$). Similar results were observed for sustained fluoride release from Beautifil®. The fluoride release was maintained at 0.70 to 0.78 PPM during day 14, 21 and 28 that was again significantly lower than fluoride values of Fuji II™ LC ($p<0.05$).

The total cumulative release of fluoride was also calculated (PPM) and both materials are compared in Fig. 2. Initially, on day 1 there was a very little difference in total cumulative fluoride release values [1.40±0.025 and 1.80±0.045 PPM (n=6)] respectively for Beautifil® and Fuji II™ LC. However the difference was consistently increased with the passage of time due to significantly higher amount of fluoride release from the Fuji IILC for any day resulting in divergent curves (Fig 2). The value of total cumulative fluoride release during 28 was 5.87±0.017 and 14.56±1.027 PPM for Beautifil® and Fuji II™ LC respectively.

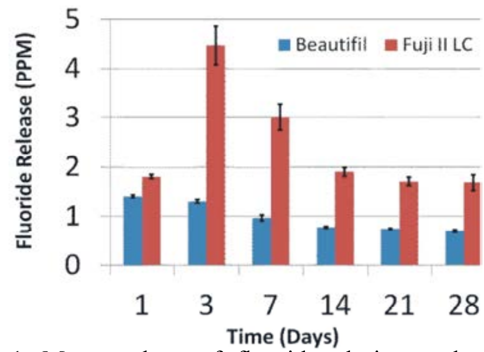

Fig. 1: Mean values of fluoride elution and standard deviation on different days (n=6)

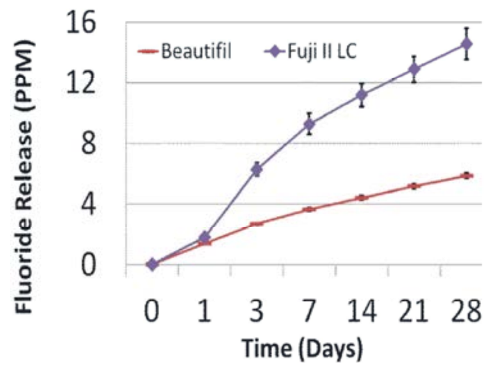

Fig. 2: Cumulative fluoride release from Beautifil® and Fuji IITM LC (n=6)

DISCUSSION

The main aim of this study was to evaluate the effect of pre-reacted glass particles on fluoride release pattern and compared it to resin modified glass ionomers Fuji II™ LC. The property of releasing fluoride in the oral cavity is one of the distinguished features of glass ionomers. Fluoride compounds are added to glass silicate during manufacturing process to act as flux and released from the glass on mixing with polyalkenoic acid [17]. The release of fluoride from glass ionomers restorations has been proven to play a vital role in oral health such as prevention of secondary caries [1, 18-20], affecting acidogenic bacteria [21] and fluoride density in enamel and dentin [22, 23]. The mechanism of fluoride release is a complex phenomenon and the decisive amount of fluoride release from glass ionomers required to inhibit dental carries cannot be established. Hence more fluoride release, maintained for a longer period of time is desired and accepted to play a beneficial role in caries prevention [24]. Increasing amount of fluoride release during initial burst and later period should be attained without compromising the physical and mechanical properties [25].

Fluoride release pattern is different for various commercially available restorative materials. However many resin modified glass ionomers are as equally efficient as conventional glass ionomers [26] and even reported of better fluoride release [27]. Materials analyzed in this study; Fuji II™ LC is resin modified glass ionomer cement [28]. Beautifil® is a giomers that was introduced about a decade ago by Shofu Int. It is a hybrid material containing inorganic and surface pre-reacted glass fillers [15] The manufacturer of Beautifil® claimed of having better mechanical and physical properties The reason behind to choose these material was to study the fluoride release pattern in relation to different composition. Similarly many other studies on fluoride release from a range of restorative materials [25,29,30], two distinct stage of fluoride release (Burst release for initial few days and sustained release) were observed from both materials under investigation.

The initial burst fluoride release is very beneficial and desired due to its proven effect in caries prevention and demineralization of dental hard tissues [31] where as sustained release increase enamel and dentin resistance to new carious lesions [32]. Fuji II™ LC was observed to release the highest amount of burst fluoride up to 6.27±0.435 PPM within 72 hours compared to only 2.7±0.059 PPM for Beautiful. Hence the former material released approximately three folds higher amount than later material. Similar trend was followed during sustained fluoride release for up to four weeks. The resultant value of total cumulative fluoride release for Fuji II™ LC at day 28 was significantly higher than total cumulative fluoride released by Beautifil® (5.87±0.173 PPM). These findings have suggested that resin modified glass ionomers material Fuji II™ LC exhibited better fluoride release properties than pre-reacted glass containing materials.

Due to the variation in experimental methodology and availability of different materials and compositions, it is difficult to compare results with exactly similar studies. In a different study [30], resin modified glass ionomers were found to release higher amounts of fluoride compared to conventional glass ionomers and nanocomposite materials. In contrast, Reactmer (A giomer material containing full reaction type pre-reacted glass particles) was observed to release higher amount of fluoride release compared to compomer (Dyract) and composites (Xeno CF) under similar conditions [29]. The correlation of these finding suggest that giomers may have better fluoride release properties than compomers and dental composites, however glass ionomers are still having better fluoride release than giomers. Some possible explanation for this difference in fluoride release may be; Resin modified glass ionomers maintain a very low surface pH for at least one hour [33]. The low surface pH can accelerate the leaching of fluoride resulting in high burst fluoride release from Fuji II™ LC. In contrast, the initial pH of giomers is less likely to be decreased due to the presence of pre-reacted glass particles [34]. Another crucial factor determining the release of fluoride is the extent of hydrogel matrix that particularly affects the earlier stages of fluoride release. This glass ionomers matrix layer facilitates the penetration of water in the materials hence releasing higher amount of fluoride [29]. Pre-reacted glass present in the Beautifil® has very little acid base reaction that results in production of no or inadequate glass ionomers matrix phase [35]. In addition, ability to release fluoride may be affect by the porosity of material; as increased porosity will facilitate the diffusion of fluoride towards external surface. The presence of resin components (In case of compomers, giomers and composites) can also change the fluoride release pattern in these materials [36].

In terms of mechanical properties, high fluoride releasing materials are weaker and may not be desired for high stress bearing areas in the oral cavity [36]. In contrast, pre-reacted glass containing materials were found significantly harder than resin modified glass ionomers and composites [37]. However for fluoride release pattern, glass ionomers have shown promising results. The reduction of fluoride release form goimers is a complex phenomenon and related to multiple factors as discussed above. However, further research is needed to evaluate either this reduced amount of fluoride release from Beautifil® is enough to perform its beneficial role clinically or not. Due to proven better mechanical properties [37], giomers may be a better choice for load bearing areas alongside frequent fluoride applications in the form of fluoridated tooth pastes and mouthwashes.

CONCLUSION

Both materials (Beautifil® and Fuji II ™ LC) used in this study showed the similar pattern of fluoride release, i.e. first the initial burst release of fluoride followed by sustained release of fluoride for four weeks. However, the amount of cumulative fluoride release from Beautifil® (giomer) material remained significantly lower than the fluoride release from Fuji II™ LC throughout the period of this study. This reduction of fluoride from beautiful may be related to lack of acid base reaction, inadequate glass matrix layer and porosity. The addition of surface pre-reacted glass particles in the resin matrix has improved physical properties as claimed by the manufacturer however, fluoride elution was observed to be lower than resin modified glass ionomers.

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