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Fluoride Release and Recharge from Different Materials Used as Fissure Sealants

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ABSTRACT

Objectives: Fluoride release/recharge properties of fissure sealants are important for their long-term inhibition of caries. This study was conducted to examine the relationship between fluoride release and recharge of pit-and-fissure sealants.

Methods: Specimens were prepared from 5 different sealant materials: Fissurit F, a conventional resin; Fuji VII, a glass-ionomer cement (GIC); Fuji II LC, a resin-modified GIC; Ionosit, a polyacid-modified composite resin (PMRC); and Aelite Flo, a flowable composite resin. Specimens stored in a polyethylene test tube containing 5.0 ml ultrapure water. On day 21, specimens were exposed to 1.23% APF gel. Fluoride release was measured using a fluoride-specific ion electrode at 1-7, 14, 21, 22, 28, 35 and 42 days.

Results: The glass-ionomer based sealants Fuji VII and Fuji II LC had significantly higher fluoride release than the other materials at all times tested ($P<.05$). Fluoride release of all materials tested increased following exposure to APF gel ($P<.05$).

Conclusions: Within the limitations of this short-term study, glass ionomer-based sealants were shown to have higher initial fluoride release as well as higher fluoride recharge capacity than other sealants. (Eur J Dent 2010;4:245-250)

Key words: Fissure sealant; Fluoride release; Fluoride recharge; Preventive dentistry; Topical fluoride.

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INTRODUCTION

Dental caries is the most common chronic disease of childhood, despite the fact that it is largely preventable.[1] Occlusal surfaces with pits and fissures have been recognized as susceptible areas for the initiation of dental caries.[2]

Application of fissure sealants is one of the most effective methods for preventing caries on occlusal surfaces.[3,4] While the principal cariostatic properties of sealants are related to their physical obstruction of pits and grooves,[2] the introduction of fluoride-releasing sealants has added another dimension to their role in preventing pit-and-fissure caries.[5]

Different fluoride-releasing materials have been used as fissure sealants, including glass ionomer cements (GIC),[6] resin-modified GICs,[7] fluoride-releasing composite sealants[8] and adhesive systems.[9] Most of the sealant materials used today are resin-based materials that possess high retention rates[10] but are clinically limited by the difficulties inherent in the use of resins in a moist environment. If complete isolation of the tooth cannot be achieved, salivary contamination will result in failure of the resin-based sealant.[11] GIC sealants represent an alternative to resin sealants, especially where resin sealants are contraindicated, as in clinical treatment of children with deeply pitted or fissured primary molars, or permanent first or second molars that have not fully emerged and whose isolation can be difficult.[11] However, while GICs provide the benefits of fluoride release, their mechanical properties, including wear-resistance, are inferior to composite resins.[12-14] In order to overcome these limitations, resin-modified GICs were introduced[12,14,15] that also differ from their precursors for their photo-polymerization ability.[16]

In vitro studies have shown that fluoride-containing dental materials can be recharged by fluoridated products.[17-19] This may contribute to their long-term effectiveness in caries inhibition.[20] Although interest in fluoride-releasing sealants and their possible anticariogenity appears to have increased, the majority of studies examining fluoride release and uptake have focused on restorative materials,[18,19,21-24] with relatively few studies looking at fluoride release and uptake of pit-and-fissure sealants.[3,25] Therefore, this in vitro study aimed to investigate the release of fluoride from five different sealants and their recharge after exposure to 1.23% acidulated phosphate fluoride (APF) gel.

MATERIALS AND METHODS

Five different materials commonly used as pit-and-fissure sealants were included in this study (Table 1).

Specimen preparation

A total of 50 specimens (10 of each material) were used in the study. The materials were prepared according to the manufacturers' instructions and placed in plastic molds 10 mm dia. x 1.0 mm deep. Excess material was removed, and a nylon thread (for suspension in solution) was imbedded into each specimen. Specimens were then pressed between two Mylar-covered glass slides and polymerized for 20 seconds using an LED curing unit (Elipar Free Light II, 3M/ESPE, St. Paul, MN, USA; light intensity:1000 mV/cm^2). Following polymerization, specimens were removed from their molds and wet ground with 600-, 800- and 1000-grit silicon carbide abrasive paper on a 300 rpm grinding machine (Buehler Metaserv, Buehler, Germany) for 10 seconds. Specimens were allowed to set for an additional 24h in a humid atmosphere at 37°C±2°C.

Initial fluoride release

Each specimen was immersed in a polyethylene tube containing 5 ml of ultrapure water (Millipore, USA) and stored in an incubator (Electromag, M5040BP, Istanbul, Turkey) at a constant temperature of 37°C. Specimens were transferred to new tubes with fresh solution every 24h for the first week and then once a week for the remainder of the experimental period.

Fluoride ion release after exposure to 1.23% APF gel. On day 21, the discs were removed from the polyethylene tubes and coated with 1.23% APF gel (12300 ppm F, pH 3.2) (Sultan Topex APF, Sultan Dental Products, Englewood, NJ, USA). After 4 min., specimens were rinsed with ultrapure water, dried with absorbent paper, placed in a clean polyethylene tube with 5 ml ultrapure water and stored at 4°C until analysis.

Fluoride release was measured at 1-7, 14, 21, 22, 28, 35 and 42 days.

Fluoride analysis

Concentrations of released fluoride ions were measured using a fluoride-specific ion electrode (ORION 9609BN, Thermo Electron Corp, MA, USA) connected to a digital ion analyzer (ORION 720A+, Thermo Electron Corp, MA, USA). Prior to each measurement, the electrode was calibrated using four standard fluoride solutions (Orion Fluorid Standart 0.1M, 940906) of 0.19, 1.9, 19 and 190 ppm fluoride. Calibration curve correlation coefficients (r^2) varied between 0.998-0.999. Measurements were performed by pipetting 3 ml of each sample solution into a clean plastic test tube, adding 3 ml of TISAB II (Total ionic strength adjustment buffer, 940906, Orion Research, Inc, Beverly, MA, USA) containing 1.2-cyclohexylenedinitrolotetraacetic acid (CDTA) (Thermo-Orion) and stirring for 3 min before measurement. Fluoride concentrations (mV) were automatically displayed on the analyzer and converted to parts per million (ppm).

Statistical analysis

Differences in fluoride concentrations among materials at different time points were analyzed using two-way Repeated Measures ANOVA and comparison of means. For each material, differences in fluoride release before and after APF application were evaluated using paired t-tests. Differences among groups in fluoride release before and after APF exposure were analyzed using Duncan's multiple range tests.

RESULTS

Mean (±SD) amounts of fluoride released from each material before exposure to APF gel (at days 1-7, 14 and 21) are shown in Table 2. Two-way repeated measures ANOVA indicated significant differences in fluoride release among materials ($P<.05$), with fluoride release from the glass ionomer-based sealants Fuji VII and Fuji II LC significantly higher than from the other sealants at all time during the test period ($P<.05$).

For all materials, the greatest amount of fluoride released occurred at 24 h. Fluoride release decreased with time, but continued throughout the entire 21-day test period up until recharge. At 24 h, Fuji VII released the most fluoride, followed by Fuji II LC, Fissurit F, Ionosit and Aelite Flo. Differences in fluoride release among all materials were statistically significant ($P<.05$), with the exception of Aelite Flo and Ionosit, which had similar amounts of fluoride release.

Mean (±SD) amounts of fluoride release from each material at day 21 and after exposure to APF gel (at days 22, 28, 35 and 42) are shown in Table 3. For all materials, a significant increased in fluoride release occurred at 24 h following exposure to 1.23% APF gel (day 22) ($P<.05$).

Fuji VII and Fuji II LC released significantly more fluoride than the other materials tested at all times measured ($P<.05$).

DISCUSSION

Pit-and-fissure sealants and topical fluorides

Table 1. Materials used in the study.

Product	Material Type	Composition	Manufacturer
Fissurit F	Conventional resin	Monomer matrix: BIS-GMA, UDMA (content 91%) Fillers: Borosilicate glass Particle size: 99% L >1 μm, NaF 3% coresponds to 1.3% fluoride content	Voco GmbH, Cuxhaven, Germany
Fuji VII	Glass-ionomer cement	Fluoroaluminium silicate glass, polyacrylic acid, polybasic carboxylic acid	GC Corp, Tokyo, Japan
Fuji II LC	Resin-modified glass-ionomer cement	Powder: fluoraluminosilicate glass Liquid: aqueous solution of polycarboxylicacid, TEGDMA and HEMA	GC Corp, Tokyo, Japan
Ionosit	Polyacid-modified resin composite	Acrylic resin, glass powder, silica, aliphatic dimethacrylate,aromatic dimethacrylate, polycarboxylic polymethacrylate	DMG Hamburg, Germany
Aelite Flo	Flowable composite resin	Ethoxylated bisphenol a dimethacrylate, TEGDMA	Bisco Inc., Schaumburg, USA

BIS-GMA, Bis-glycidyl dimethacrylate; UDMA, urethane dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; TEGDMA, triethleneglycol dimethacrylate.

are the primary preventive treatment for dental caries and are widely used in public dental programs.[6,26] The combination of sealant and topical fluoride application has shown synergistic anticariogenic properties stemming from the rechargeability of fluoride-releasing fissure sealants.[25] This study analyzed fluoride release and recharge of five different materials exposed to 1.23% APF gel.

In this study, during the first day following application, high concentrations of fluoride were released from the glass ionomer-based materials used as sealants, but not from the other materials tested. This initial high level of fluoride release has been referred to in a previous study as the "burst effect" and has been attributed to the rapid release of fluoride from the glass particles as they are dissolved by polyalkenoate acid during setting.[21] The slower release of fluoride during subsequent days has been attributed to the slower dissolution of glass particles into the acidified water of the hydrogel matrix.[27]

In general, a direct relationship exists between the amount of fluoride present in the cement and the amount of fluoride released.[28,29] In the present study, higher amounts of fluoride were released from Fuji VII and Fuji II LC when compared to the other materials tested. The manufacturers of Fuji VII GIC claim that this material releases much greater amounts of fluoride than other high-strength GICs. In the present study, Fuji VII released twice the amount of fluoride as Fuji II LC at 24 h; however, by day 4, Fuji II LC and Fuji VII released fluoride in similar amounts.

In comparison to Fuji II LC and Fuji VII, Fissurit F, Ionosit, Aelite Flo released less fluoride, which contained fluoroaluminasilicate glass. The fluoridated glass within these materials has little or no glass ionomer matrix phase because of the lack of any significant acid-base reaction.[30]

The APF gels that are recommended as preventive treatment for caries contain phosphoric acid, which etches the enamel and thus enhances fluoride uptake.[31] All the materials tested in the present study were found to be capable of fluoride uptake and subsequent release. For all materials, fluoride release increased following APF exposure; however, one week after exposure to APF gel, the fluoride release rates of all the materials tested experienced a sharp drop to their initial pre-exposure levels.

According to Preston et al,[32] the exact mechanism of fluoride recharge is unknown. Material composition, the diffusion of fluoride through the material and differences in surface energy may influence fluoride recharge and subsequent re-

Table 2. Fluoride release from sealant materials (µg/mm^2) (mean and sd). Differences in superscript letters indicate statistically significant differences within columns, and differences in superscript numbers indicate significant differences within rows (P<.05) (1, A= Best Values)

Groups	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 14	Day 21
GIC (Fuji VII)	$213.65\pm43.34^{A,1}$	$58.56\pm14.04^{A,2}$	$43.42\pm11.35^{A,2,3}$	$33.52\pm11.59^{A,3,4}$	$30.51\pm13.40^{A,3,4}$	$26.95\pm11.20^{A,3,4}$	$21.40\pm10.05^{A,3,4}$	$19.56\pm8.67^{A3,4}$	$17.07\pm9.66^{A,4}$
Resin-modified GIC (Fuji II LC)	$99.50\pm7.43^{B,1}$	$41.84\pm3.21^{B,2}$	$33.40\pm2.27^{B,3}$	$28.70\pm3.26^{A,4}$	$23.98\pm1.54^{A,5,6}$	$23.11\pm1.73^{A,5,6}$	$26.14\pm1.11^{A,4,5}$	$22.67\pm1.97^{A,5,6}$	$21.41\pm0.75^{A,6}$
Conventional resin (Fissurit F)	$50.84\pm8.40^{C,1}$	$6.94\pm1.56^{C,2}$	$5.05\pm0.62^{C,2,3}$	$4.87\pm0.79^{B,2,3}$	$3.88\pm0.56^{B,2,3}$	$3.42\pm0.65^{B,2,3}$	$2.80\pm0.51^{B,2,3}$	$1.42\pm0.11^{B,3}$	$1.38\pm0.11^{B,3}$
Polyacid modified composite resin (Ionosit)	$10.64\pm2.56^{D,1}$	$1.74\pm0.16^{C,2}$	$0.77\pm0.64^{C,2,3}$	$0.48\pm0.03^{B,3}$	$0.48\pm0.03^{B,3}$	$0.42\pm0.02^{B,3}$	$0.39\pm0.02^{B,3}$	$0.35\pm0.03^{B,3}$	$0.30\pm0.05^{B,3}$
Composite resin (Aelite Flo)	$0.82\pm0.25^{D,1}$	$0.45\pm0.32^{C,2}$	$0.36\pm0.01^{C,2,3}$	$0.99\pm0.96^{B,3,4}$	$0.21\pm0.04^{B,4,5}$	$0.18\pm0.05^{B,4,5}$	$0.22\pm0.01^{B,4,5}$	$0.17\pm0.02^{B,4,5}$	$0.13\pm0.01^{B,5}$

Table 3. Fluoride release from materials before and after fluoride treatment (FT) (µg/mm^2) (mean and sd).

Groups	21. day (day before FT)	22. day (Fluoride uptake)	28. day (One week after FT)	35. day (Two weeks after FT)	42. day (Three weeks after FT)
GIC (Fuji VII)	$17.07\pm9.66^{A,1,2}$	$71.44\pm6.60^{A,1}$	$10.38\pm4.51^{A,2,3}$	$8.50\pm4.38^{A,3}$	$7.11\pm3.14^{A,3}$
Resin-modified GIC (Fuji II LC)	$21.41\pm0.75^{A,1,2}$	$72.69\pm8.42^{A,1}$	$17.75\pm1.57^{B,2,3}$	$14.12\pm1.49^{B,3,4}$	$10.84\pm1.18^{B,4}$
Conventional resin (Fissurit F)	$1.38\pm0.11^{B,2}$	$8.32\pm2.69^{B,1}$	$0.88\pm0.16^{C,2}$	$0.57\pm0.10^{C,2}$	$0.48\pm0.08^{C,2}$
Polyacid-modified composite resin (Ionosit)	$0.30\pm0.05^{B,2}$	$10.39\pm2.83^{B,1}$	$0.34\pm0.05^{C,2}$	$0.29\pm0.05^{C,2}$	$0.27\pm0.03^{C,2}$
Composite resin (Aelite Flo)	$0.13\pm0.01^{B,2}$	$5.50\pm1.26^{B,1}$	$0.21\pm0.01^{C,2}$	$0.14\pm0.01^{C,2}$	$0.12\pm0.03^{C,2}$

Differences in superscript letters indicate statistically significant differences within columns, and differences in superscript numbers indicate significant differences within rows (P<.05) (1, A= Best values) lease.[33-35] The results of the present study are in line with the observation by Xu and Burgess[36] that materials with higher initial fluoride release have higher recharge capacity.

Previous studies have shown that conventional and resin-modified GICs are capable of recharge, whereas resin-based materials are not.[37-39] In the present study, fluoride release from Fissurit F, Ionosit and Aelite Flo was found to increase following exposure to APF gel, but to a much lesser extent than from the glass ionomer-based materials. Moreover, the fluoride released from Fissurit F, Ionosit and Aelite Flo was most likely related to surface-retained fluoride.

A number of limitations to this in vitro study should be noted vis-a-vis clinical application. First, the ultrapure water used as a medium for evaluating fluoride release cannot accurately simulate the liquid media to which sealant materials are exposed in the oral cavity, e.g., saliva (in patients not at risk of caries) and dental plaque fluid (in patients at risk of caries or caries-active). Second, the recharging of sealant materials in this study was designed to simulate professional fluoride application using APF, whereas simulation of sealant recharge from daily brushing using a fluoride dentifrice would have more clinical relevance. These issues and short-term nature of the study should be taken into consideration in future studies.

CONCLUSIONS

Due to their high degree of fluoride release and their ability to act as rechargeable devices for the slow release of fluoride, glass ionomer-based sealants can be recommended for treating children at a high risk of caries.

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