Journal of Oral Science, Vol. 46, No. 1, 45-50, 2004

Original

In vitro inhibition of caries-like lesions with fluoride-releasing materials

Sis Darendeliler Yaman[§], Özgür Er[§], Mehmet Yetmez[†] and Gülten Alan Karabay[‡]

[§]Department of Restorative Dentistry, Faculty of Dentistry, Gazi University,
[†]Department of Engineering Sciences, Middle East Technical University,
[‡]Department of Histology and Embryology, Başkent University,
Ankara, Turkey

(Received 4 August 2003 and accepted 23 January 2004)

Abstract: The aim of this study was to compare the *in vitro* caries inhibition of various resin-based materials. Class V cavities were prepared in twenty-five freshly extracted human premolar teeth which were then restored with glass-ionomer cement (Chemfill II), compomer (Compoglass F, Dyract AP) and composite resin (Tetric Ceram and Z 100). The teeth were submerged in an acid gel for 6 weeks. Each specimen was sectioned. These sections were left in water for 24 hours, and then examined using polarized light microscopy. The lesion consisted of two parts, the outer surface lesion and the cavity wall lesion. There was no significant difference in the body depth of the outer lesion and in the depth of the wall lesion among teeth restored with Compoglass F, Dyract AP and Chemfill II ($P > 0.05$). There was a significant difference between those restored with Z 100 and Tetric Ceram ($P < 0.05$). The length of the wall lesion for the teeth restored with Chemfill II was significantly smaller than that in the remaining groups ($P < 0.05$). The length of the wall lesion for teeth restored with Tetric Ceram and Z 100 was significantly higher than in the remaining groups ($P < 0.05$). These results suggest that composite materials and compomer provide less caries inhibition than glass-ionomer cements. (J. Oral Sci. 46, 45-50, 2004)

Correspondence to Dr. Sis Darendeliler Yaman, Department of Restorative Dentistry and Endodontics, Faculty of Dentistry, Gazi University, 06510 Emek Ankara, Turkey
Tel: +90 312 212 62 20 / 351
Fax: +90 312 223 92 26
Email: sisyaman@gazi.edu.tr

Key words: artificial caries; compomer; composite resin; glass-ionomer cement.

Introduction

Secondary caries is a significant reason for the replacement of dental restorations (1,2). Marginal leakage is thought to be responsible for development of secondary caries (3-5). The release of fluoride by dental materials is aimed at inhibiting secondary caries. Fluoride contributes to anticariogenicity by inhibiting tooth demineralization and increasing the potential for tooth structure remineralization. For these reasons fluoride has been added into various restorative materials (6). One such material is glass ionomer cement, which possesses the property of releasing fluoride ions into the adjacent tooth structure and preventing microleakage and secondary caries. Another restorative material that releases fluoride is compomer, which possesses some properties that are characteristic of glass ionomers and some that are characteristic of composites. Recently composite resin has been formulated to release fluoride (7-9). Fluoride uptake has been shown to occur in enamel and dentine adjacent to fluoride-releasing composite resin material (10).

The aim of this study was to compare the caries inhibition of fluoride-containing restorative materials at the margins of class V restorations using an acidified gel technique to create caries-like lesions around restorations.

Materials and Methods

Twenty-five sound human permanent premolar teeth were used for the study. These teeth had been extracted for orthodontic purposes. After extraction the teeth were washed, cleaned and stored in distilled water. Class V cavities measuring approximately 3 × 1.5 × 3 mm were prepared on both buccal and lingual surfaces of each tooth using a fissure diamond bur (836/012-6 ML Diatech, Switzerland) in a high-speed handpiece with water cooling. The bur was always held at right angles to the tooth surface to produce a cavosurface angle close to 90°. The cavity margins were finished with a flat bur (837/014 North Bel Int. Italy) using a slow-speed handpiece. After rinsing with water, the cavities were dried with air and filled with the restorative materials presented in Table 1. Five different restorative materials were used in the study and each restorative material was used to restore a group of five teeth. Since cavity preparations were made on both buccal and lingual surfaces, there were ten cavity preparations altogether for each different restorative material.

Group 1 was restored with Chemfill II (DeTrey, Dentsply, Germany). The cement was mixed at room temperature and placed into the cavity, and then coated with the manufacturer's recommended varnish.

Group 2 was restored with Compoglass F (Vivadent Ets., Schaan/Liechtenstein). The tooth was etched with 37% phosphoric acid gel (Etching Gel Vivadent Ets, Schaan, Liechtenstein) for 15 s. The etching gel was thoroughly rinsed off with water and the preparations were dried. According to the manufacturer's instructions, Syntac® Single-Component™ was applied to the enamel and dentin surfaces. Compoglass F was then incrementally applied in accordance with the manufacturer's instructions. It was light-cured for 40 s.

Group 3 was restored with Dyract AP (Dentsply DeTrey GmbH, Germany). The tooth was etched with 36% phosphoric acid gel (De Trey Conditioner) on cavity surfaces for 15 s beginning at the enamel margins, then thoroughly rinsed, and excess water was removed. According to the manufacturer's instructions, Prime & Bond® 2.1 was applied to the enamel and dentin surfaces. Dyract AP was immediately and incrementally applied in accordance with the manufacturer's instructions. It was light-cured for 40 s.

Group 4 was restored with Z 100 (3M USA). The tooth was etched with 37% phosphoric acid gel (Gel Etchant, Kerr Corporation, CA, USA) on cavity surfaces for 15 s begining at the enamel margins, then the etching gel was thoroughly rinsed off and excess water was removed by gentle air blowing. According to the manufacturer's instructions, Scotchbond Multipurpose Primer was applied to the enamel and dentin surfaces, and then Scotchbond Multipurpose Adhesive (3M Dental) was applied. Z 100 was later incrementally applied in accordance with the manufacturer's instructions. It was light-cured for 40 s.

Table 1 Mean and standard deviation measurements of lesions around different restorative materials

	Outer Lesion Body Depth (µm)	**Wall Lesion Body Depth (µm)**	**Wall Lesion Lesion Length (µm)**
Chemfill II	**101.7 ± 29.9**	**41.3 ± 14.5**	**78.5 ± 23.5**
Compoglass F	**144.0 ± 68.9**	**50.6 ± 23.3**	**154.9 ± 65.2**
Dyract AP	**139.3 ± 59.5**	**47.5 ± 23.5**	**153.4 ± 59.8**
Tetric Ceram	**209.6 ± 41.8**	**120.3 ± 20.7**	**219.0 ± 31.8**
Z 100	**240.7 ± 22.7**	**131.2 ± 21.5**	**246.9 ± 13.8**

Group 5 was restored with Tetric Ceram (Vivadent Ets., Schaan/Liechtenstein). The tooth was etched with 37% phosphoric acid gel (Gel Etchant, Kerr Corporation, CA, USA) for 15 s on cavity surfaces, begining at the enamel margins. The etching gel was thoroughly rinsed and the preparations were dried. According to the manufacturer's instructions, Syntac® Single-Component™ was applied. Tetric Ceram was then incrementally applied in accordance with the manufacturer's instructions. It was light-cured for 40 s.

All restorations were polished with Sof-Lex disks (3M Dental Products, St Paul, USA) after 24 h. The teeth were then thermocycled for 200 cycles between 5° and 55° with a dwell time of 20 s. The teeth were then coated with an acid-resistant varnish within 1 mm of the cavosurface margins surrounding the restorations. The teeth were immersed in acid gel for 6 weeks at 37°. The gel contained 10% methylcellulose and 0.1 M lactic acid, and the pH was adjusted to 4.5 with potassium hydroxide. At the end of the exposure period each specimen was removed from the gel, washed in distilled water and sectioned longitudinally through the restorations using a diamond sectioning saw. The section thickness was about 80 - 100 µm. The sections were then soaked in water for 24 hours and examined using polarized light microscopy. The lesion consisted of two parts, the outer surface lesion and the cavity wall lesion. Figure 1 shows schematically the location of the outer and wall lesions. All measurements from the two sections of each lesion were averaged and the results were compared statistically using the Mann-Whitney *U* test.

Results

After a six-week period of exposure to acidified gel, caries-like lesions were produced. Figures 2 to 5 show these outer and wall lesions. Table 1 shows the measurements of lesions around the restorative materials of the test groups. Table 2 shows a statistical comparison of lesions found in different restorative materials. When the results of the outer lesions were evaluated, it was found that there was no significant difference in the body depth of the outer lesion among teeth restored with Compoglass F, Dyract AP and Chemfill II ($P > 0.05$). There was significant difference between Z 100 and Tetric Ceram ($P < 0.05$), both of which had significantly higher values than the other groups ($P < 0.05$).

When the results of the wall lesions were evaluated, it was found that there was no significant difference in the depth of the wall lesions among teeth restored with Compoglass F, Dyract AP and Chemfill II ($P > 0.05$). There was also no significant difference between Z 100 and Tetric Ceram ($P > 0.05$). Tetric Ceram and Z 100 had significantly higher values than the other groups ($P < 0.05$).

When the results of the wall lesion length were evaluated, it was found that the teeth restored with Chemfill II had significantly smaller wall lesion length than the other groups ($P < 0.05$). There was no significant difference between Compoglass F and Dyract AP ($P > 0.05$). There was significant difference between Z 100 and Tetric Ceram ($P < 0.05$). Tetric Ceram and Z 100 had significantly higher values than the other groups ($P < 0.05$).

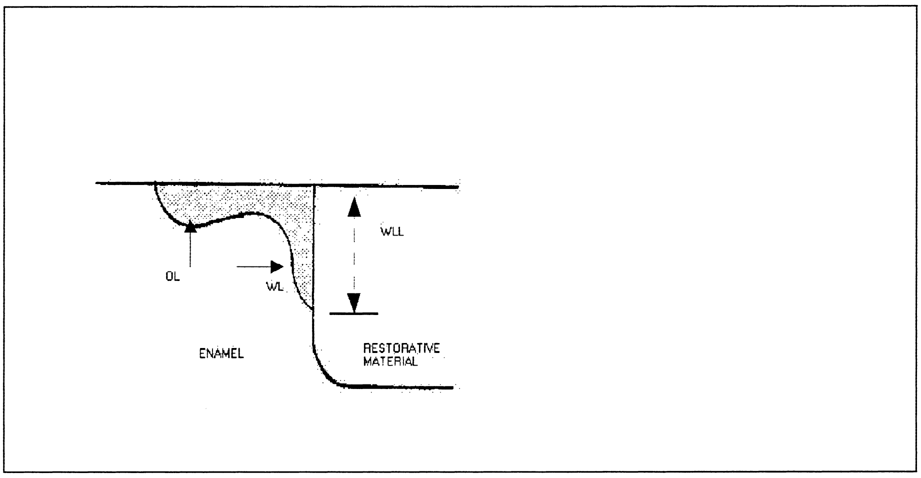

Fig. 1 Schematic drawing of lesions produced in enamel after the experimental period.
OL: Outer surface lesion is measured as the largest distance lesion.
WL: Wall lesion is measured as the largest distance between the restoration and inner border of lesion.
WLL: Wall lesion length is measured from enamel surface to the innermost extended portion of the WL towards the dentinoenamel junction.

Discussion

Although the materials have been developed in recent years, microleakage has still not been prevented between the tooth and the restorative material. If microleakage of bacteria, fluids and acidic products takes place along the enamel-restoration interface, secondary caries is likely to develop (6). The development of secondary caries around any restorative material is determined by the materials (shrinkage, solubility, fluoride content, permeability) and its clinical performance (6,11). Histological studies of natural enamel caries and chemical studies of artificial lesions have provided a deeper understanding of the phenomenon of caries lesion formation (12). Although many model systems have been developed to simulate the caries process, most of these systems have been limited to the study of demineralized enamel. One of the systems most commonly used to stimulate enamel demineralization is the acidified gel technique (13-15).

In this study, the efficiency of creating caries-like lesions by using an acid-gel technique has been investigated and the cariostatic effects of fluoride-containing materials have been compared.

The results showed that glass-ionomer cement had an inhibiting effect on the formation of caries-like lesions when compared to compomers and composite resins. Glass ionomer cements produced a reduced lesion height close to the fillings. This effect is presumed to be related to the dissolution of fluoride from the material. It has been shown in previous studies that glass-ionomer materials provide significant protection against caries-like attacks at the enamel and restoration interfaces (16-19). The fluoride released from glass-ionomer cement is not lost over time

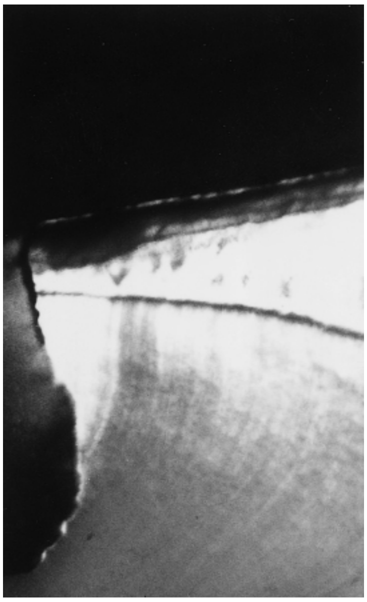

Fig. 2 Caries-like lesion formed in enamel around a compomer-restored cavity. It consists of an outer surface lesion (OL) and a cavity lesion (WL).

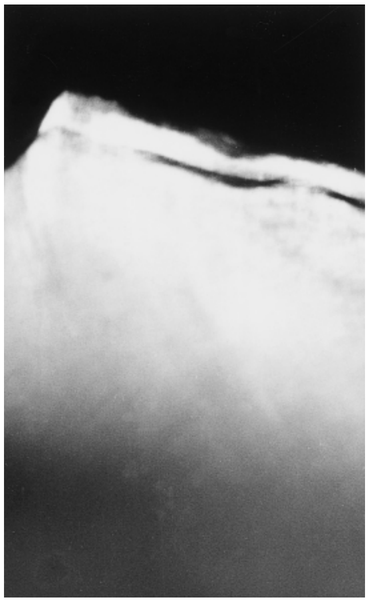

Fig. 4 Caries-like lesion formed adjacent to glass-ionomer cement-restored cavity.

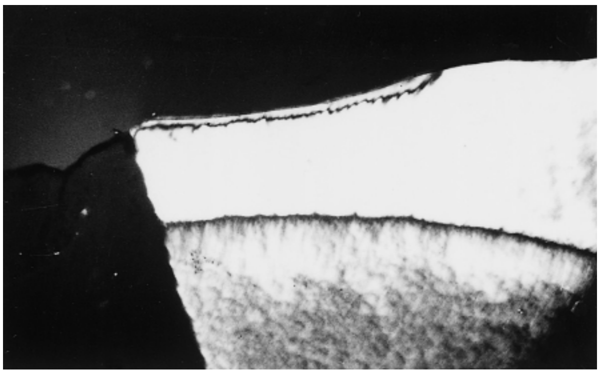

Fig. 3 Caries-like lesion formed adjacent to compomer-restored cavity.

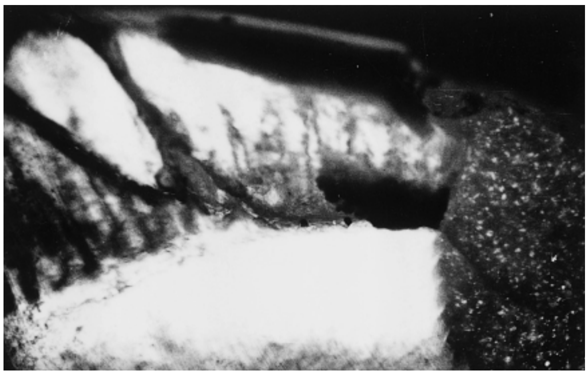

Fig. 5 Caries-like lesion formed adjacent to composite resin-restored cavity.

Table 2 Statistical comparison of lesions found in different restorative materials

Independent group comparison-nonparametric analysis

Outer lesion ($P \leq 0.05$)	Compoglass F	Dyract AP	Z 100	Tetric Ceram	Chemfill II
Compoglass F		$P = 0.924$	$P = 0.000$	$P = 0.004$	$P = 0.107$
Dyract AP	$P = 0.924$		$P = 0.000$	$P = 0.001$	$P = 0.086$
Z 100	$P = 0.000$	$P = 0.000$		$P = 0.026$	$P = 0.000$
Tetric Ceram	$P = 0.004$	$P = 0.001$	$P = 0.026$		$P = 0.000$
Chemfill II	$P = 0.107$	$P = 0.086$	$P = 0.000$	$P = 0.000$	

Wall lesion depth ($p \leq 0.05$)	Compoglass F	Dyract AP	Z 100	Tetric Ceram	Chemfill II
Compoglass F		$P = 0.655$	$P = 0.000$	$P = 0.000$	$P = 0.298$
Dyract AP	$P = 0.655$		$P = 0.000$	$P = 0.000$	$P = 0.617$
Z 100	$P = 0.000$	$P = 0.000$		$P = 0.152$	$P = 0.000$
Tetric Ceram	$P = 0.000$	$P = 0.000$	$P = 0.152$		$P = 0.000$
Chemfill II	$P = 0.298$	$P = 0.617$	$P = 0.000$	$P = 0.000$	

Wall lesion height ($P \leq 0.05$)	Compoglass F	Dyract AP	Z 100	Tetric Ceram	Chemfill II
Compoglass F		$P = 0.978$	$P = 0.000$	$P = 0.003$	$P = 0.000$
Dyract AP	$P = 0.978$		$P = 0.000$	$P = 0.001$	$P = 0.000$
Z 100	$P = 0.000$	$P = 0.000$		$P = 0.015$	$P = 0.000$
Tetric Ceram	$P = 0.003$	$P = 0.001$	$P = 0.015$		$P = 0.000$
Chemfill II	$P = 0.000$	$P = 0.000$	$P = 0.000$	$P = 0.000$	

but becomes incorporated into the mineral component of enamel, cementum and dentine, possibly as fluoridated hydroxyapatite (20). The glass-ionomer cements protected not only the cavity wall but also the zones adjacent to the restoration. This could be because the cement has better quality fluoride that is liberated in greater quantities (21). Fluoride release from conventional glass-ionomer cements has been shown *in vitro* to be taken up into adjacent enamel and results in reduced enamel solubility (22,23). A large amount of fluoride is released initially, followed by a relatively constant smaller amount over an extended period of time (22,23).

Compoglass F provided similar caries inhibition *in vitro* to that of Dyract AP. Both of these materials were less able to inhibit caries than glass-ionomer cement. Millar (23) found that there is no significant difference between these compomers and they provide less caries inhibition than glass-ionomer cement. A compomer has been shown not to take up fluoride (24) therefore the clinical caries inhibition around a compomer is likely to remain less than that around a conventional glass-ionomer cement.

When the composites of the study were evaluated, the results indicated that the fluoride-containing composite resin had a greater tendency to inhibit the development of caries-like lesions than the non fluoride-containing composites. Fluoride-containing Tetric Ceram showed a greater inhibitory effect on caries-like lesions than Z 100, probably because Z 100 does not contain fluoride. Dijkman et al. (25) used fluoride and non fluoride-containing composite resins and found that fluoride-contaning composite resins reduced demineralization. Dionsopholus et al. (26) showed that in fluoride-releasing composite resin restorations, recurrent caries lesions were not reduced significantly more than in non fluoride composite resin restorations. Donly (9) demostrated that Heliomolar releases fluoride not only to inhibit caries, but also to remineralize incipient caries *in vitro*.

In conclusion, this *in vitro* study showed that glass ionomer cement and compomers may significantly reduce secondary caries in enamel. Although compomers are less effective than glass-ionomer cements in inhibiting secondary caries, they can be used as an alternative in class V restorations. If a class V composite resin restoration is to be placed, the use of fluoride-containing composite resin would be the most appropriate.

References

1. Silva M, Zimmerman BF, Weinberg R, Sarkar NK (1987) Corrosion and artificial caries-like lesions around amalgam restorations. Aust Dent J 32, 116-119
2. Mjor IA (1981) Placement and replacement of restorations. Oper Dent 6, 49-54
3. Kidd EAM (1976) Microleakage in relation to amalgam and composite restorations. British Dent J 141, 305-310
4. Staninec M, Jow RW, Kircos LT, Hoover CL (1988) *In vitro* caries induction at the tooth amalgam interface. Dent Mat 4, 72-76
5. Pimenta LAF, Fontana UF, Curcy JA, Serra MC, Elderton RJ (1998) Inhibition of demineralization *in vitro* around amalgam restorations. Quintessence Int 29, 363-367
6. Hattab FN, Mok NY, Agnew EC (1989) Artificially formed caries like lesions around restorative materials. J Am Dent Assoc 118, 193-197
7. Arends J , Ruben J (1988) Fluoride release from a composite resin. Quintessence Int 19, 513-514
8. Dijkman GE, Devries J, Lodding A , Arends J (1993) Long-term fluoride release of visible light-activated composites *in vitro*: a correlation with in situ demineralization data. Caries Res 27, 117-123
9. Donly KJ, Segura A, Wefel JS , Hogan MM (1999) Evaluating the effects of fluoride-releasing dental materials. On adjacent interproksimal caries. J Am Dent Assoc 130, 817-825
10. Zimmerman BF, Rawls HR, Querens AE (1984) Prevention of *in vitro* secondary caries with an experimental fluoride-exchanging restorative resin. J Dent Res 63, 689-692
11. Dionysopoulos P, Kotsanos N , Papadogianis Y (1996) Secondary caries formation *in vitro* around glass ionomer-lined amalgam and composite restorations. J Oral Rehabil 23, 511-519
12. Featerstone JD, Holmen L, Thylstrup A, Fredebo L, Shariati M (1985) Chemical and histological changes during development of artificial caries. Caries Res 19, 1-10
13. Wefel JS, Heilman JR, Jordan TH (1995) Comparisons of *in vitro* root caries models. Caries Res 29, 204-209
14. Feagin F, Graves CN (1998) Evaluation of the effects of F in acidified gelatin gel on root surface lesion development *in vitro*. Caries Res 22, 145-149
15. Grieve AR, Jones JC (1980) An *in vitro* study of marginal leakage associated with composite restorations using an acidified agar technique. J Oral Rehabil 7, 215-223
16. Pereira PN, Inokoshi S, Tagami J (1998) *In vitro* secondary caries inhibition around fluoride releasing materials. J Dentist 26, 505-510
17. Hicks MJ, Flaitz CM, Silverstone LM (1986) Secondary caries formation *in vitro* around glass ionomer restorations. Quintessence Int 17, 527-532
18. Dionysopoulos P, Kotsanos N, Papadogiannis Y, Konstandinidis A (1998) Artificial caries formation around fluoride-releasing restorations in roots. J Oral Rehabil 25, 814-820
19. Derand T, Johansson B (1984) Experimental secondary caries around restorations in roots. Caries Res 18, 548-554
20. Retief DH, Bradley EL, Denton JC, Switzer P. (1984) Enamel and cementum fluoride uptake from a glass-ionomer cement. Caries Res 18, 250-257
21. Valenzuela VS, Abarca AM, Silava NDC, Franco ME, Huerta JM (1994) *In vitro* inhibition of marginal caries-like lesions with Fluoride-containing amalgam. Oper Dent 19, 91-96
22. Forss H, Seppa L (1990) Prevention of enamel demineralization adjacent to glass-ionomer filling materials. Scand J Dent Res 98, 173-178
23. Millar BJ, Abiden F, Nicholsan JW (1998) *In vitro* caries inhibition by polyacid-modified composite resins (‘Compomers’). J Dentist 26, 133-136
24. Forsten L (1995) Resin-modified glass-ionomer cements: fluoride release and uptake. Acta Odontol Scand 53, 222-225
25. Dijkman GE, de Vries J, Arends J (1994) Secondary caries in dentine around composites: a wavelength-independent microradiographical study. Caries Res 28, 87-93
26. Dionysopoulos P, Kotsanos N, Papadogiannis Y, Konstandinidis A (1998) Artificial secondary caries around two new F-containing restoratives. Oper Dent 23, 81-86