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Study on the potential inhibition of root dentine wear adjacent to fluoride-containing restorations

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Abstract The purpose of this in vitro study was to determine whether the vicinity of root dentine that had been restored with fluoride-releasing materials was at reduced risk for erosive/abrasive wear compared to root dentine restored with a non-fluoride-containing material. According to a randomized complete block design, standardized cavities prepared on the surface of 150 bovine root dentine slabs were restored with glass-ionomer cement, resin-modified glass ionomer, polyacid-modified resin composite, fluoride-containing or conventional composite. Specimens were coated with two layers of an acid-resistant nail varnish exposing half of the dentine surface and half of the restoration. Subsequently, specimens were either eroded in an acidic drink or left uneroded, then exposed to artificial saliva and abraded in a toothbrushing machine. Wear depth in the vicinity of restorations was quantified by a stylus profilometer, based on the nonabraded areas surrounding the erosion/abrasion region. Two-way ANOVA did not demonstrate significant interaction between restoratives and eroded-uneroded dentine ($p = 0.5549$) nor significant difference among restorative materials ($p = 0.8639$). Tukey's test ascertained that the wear depth was higher for eroded than for uneroded groups. Fluoride-releasing materials seemed to negligibly inhibit wear in the vicinity of restored root dentine subjected to erosive/abrasive challenges.

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Introduction

Given that individuals are keeping their natural dentition longer, the potential for pathological cervical wear increases and may constitute a concern [1, 2]. A major factor in tooth wear is the interaction between erosion by dietary acids and abrasive forces. In effect, the softening effect of acids, caused by partial demineralisation, renders dentine vulnerable to physical insults such as those provided by toothbrushing [3–5].

There is some evidence that fluoride may assist in strengthening dental hard tissues against dental erosion [6, 7]. Specifically with regard to dentine, topical fluoride appears to be capable of rehardening eroded surfaces [8] and enhancing its abrasion resistance [9]. However, the role of fluoride-releasing restorative materials on erosion prevention is unestablished. If it is assumed that fluoride released from glass-ionomer cements (GICs) can hamper secondary caries development [10–12], it may also be hypothesized that such materials could have comparable effects on erosion, preventing the formation of defects on tooth substrate adjacent to the restoration margins.

Besides GICs, other restoratives containing releasable fluoride—resin-modified glass ionomers (RMGIs), polyacid-modified resin composites (PMRCs) and fluoride-containing resin composites (FCRCs)—have also been considered as possible vehicles for preventing dentine root demineralisation [11, 13, 14]. As the rate of fluoride release is material-dependent, with GICs leaching about

10–50 times more fluoride than FCRCs [15, 16], and RMGIs and PMRCs providing intermediate amounts [17, 18], it is likely that erosive/abrasive wear prevention, if any, could be modulated by such magnitudes of release.

Based on the rationales outlined above, this study sought to investigate whether prevention of erosive/abrasive wear could be achieved in the vicinity of root dentine restored with fluoride-releasing materials.

Materials and methods

Experimental design

This study was a completely randomized experimental design with a factorial 5 × 2 array with 15 experimental units per treatment. Factors examined comprised: (1) *restorative system* at 5 levels a glass-ionomer cement, a resin-modified glass ionomer, a polyacid-modified resin composite, a fluoride-containing resin composite or a conventional composite, as listed in Table 1 and (2) *substrate condition* at 2 levels (eroded and uneroded). The response variable was wear depth, expressed in μm.

Preparation of root dentine slabs

Seventy-five roots of bovine incisors, which had been sectioned from crowns through the cemento-enamel junction buccolingually, were gently scraped of superficial debris and soft tissue, cleaned and stored in a 0.1% thymol solution. Two slabs (6 mm long × 5 mm wide × 2 mm thick) were cut from each root piece (Fig. 1A) using a low speed water-cooled diamond saw (Minitom, Struers A/S, Rodovre, Denmark). The slabs were positioned in a polyvinylchoride ring and polyester resin was poured around the specimen and allowed to harden. Then, embedded slabs were lapped and polished with 400-, 600-, and 1200-grit Al_2O_3 grinding papers (Fig. 1B) and sonicated for 10 min in deionized water.

Standardized box-shaped cavities (2 mm in length, 2 mm in width and 1 mm in depth) were prepared at the middle of the embedded slabs using a milling machine (MPC, ElQuip, São Carlos, SP, Brazil) and a cylindrical diamond bur (#2096, KG Sorensen, Barueri, SP, Brazil) in a high-speed handpiece under watercooling (Fig 1C–D). The burs were replaced after every five preparations.

Restorative and polishing procedures

Samples were restored (Fig. 1E) following the manufacturer's recommendations (Table 1). The restored specimens were individually soaked in artificial saliva [19] at 37 ± 1 °C for 24 h. Remnants of restorative materials were removed from the specimens' surface by polishing with 600- and 1200-grit Al_2O_3 papers (Fig. 1F). Then, specimens were soaked in artificial saliva at 37 ± 1 °C for 24 h.

Specimens were coated with two layers of an acid-resistant nail varnish exposing half of the dentine surface and half of the restoration (Fig. 1G). The protected area acted as a reference surface for the determination of lost material after erosive/abrasive challenges.

Erosive/abrasive challenges

Over the experimental period, specimens were subjected to a 5-day erosive/abrasive regimen based in part on a protocol described previously [9], as shown in Fig. 2. On each day, specimens were subjected to 5 cycles, each one consisting of the immersion in 7 mL of either a lemonade-like carbonated soft drink (Sprite Diet, Companhia de Bebidas

Table 1 Characterization of the restorative systems tested

Restorative system	Classification	Dentine pre-treatment	Curing	Surface protection
Ketac-fil *Plus*–Espe GmbH (powder: 70201103952; liquid: 70201104018)	GIC	–	Allowed to cure for 7 min	Fuji Varnish (0205241)
Fuji II LC *Improved*–GC Corp(0205201)	RMGI	GC Dentine Conditioner (0205161)	20 s	Fuji Varnish (0205241)
Dyract AP–Dentsply Caulk(0108000442)	PMRC	H_3PO_4 34% (63783) Prime&Bond NT (007000350)	40 s	–
Surefil–Dentsply Caulk (010726)	FCRC	H_3PO_4 34% (63783) Prime&Bond NT (007000350)	40 s	–
Filtek Z250–3M Dental Products (2XX)	CRC	H_3PO_4 35% (2YK) Single Bond (27112)	20 s	–

Batch numbers in parentheses

GIC = conventional glass-ionomer cement; RMGI = resin-modified glass-ionomer; PMCR = polyacid-modified composite resin; FCRC = fluoride-containing resin composite; CRC = conventionl resin composite

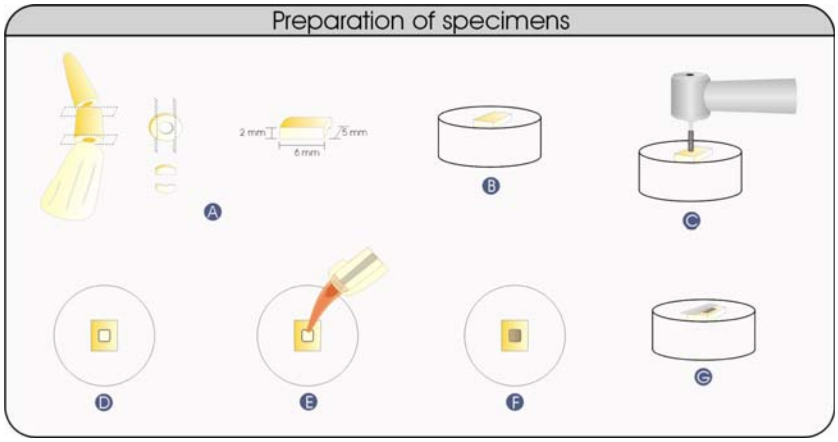
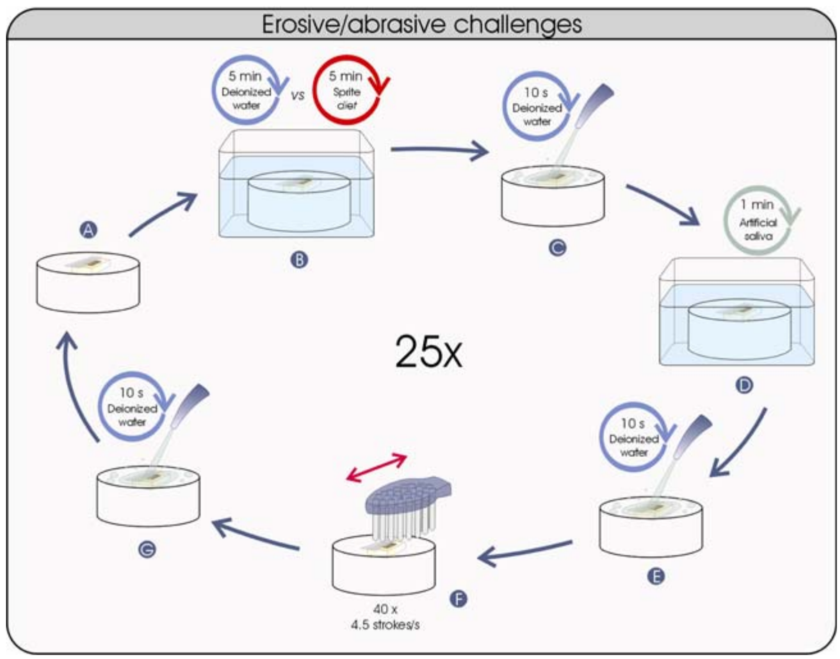


Fig. 1 Schematic drawing of the preparation of specimens: root dentine slabs were cut from bovine incisors (**A**), embedded in polyester resin, ground flat and polished (**B**). Using a milling machine (**C**), cavities were prepared (**D**). Restorations were made with either glass-ionomer cement, resin-modified glass ionomer, polyacid-modified resin composite, fluoride-containing or conventional composite (**E**). Remnants of restorative materials were removed from the specimens' surface by polishing (**F**). Specimens were coated with an acid-resistant varnish exposing half of the dentine surface and half of the restoration (**G**)

Fig. 2 Schematic drawing of erosive/abrasive challenges: for 25 times, specimens (**A**) were either eroded in an acidic drink or left uneroded (**B**), rinsed (**C**), exposed to artificial saliva (**D**), rinsed (**E**), abraded in a toothbrushing machine (**F**) and finally rinsed (**G**)



Ipiranga, Ribeirão Preto, SP, Brazil) or deionized water (control) for 5 min, rinsing with deionized water for 10 s, followed by exposure to 7 mL of artificial saliva for 1 min and rinsing. Subsequently, specimens were subjected to 40 brush strokes in an automatic toothbrushing machine that has been described in detail elsewhere [20]. Briefly, specimens were subjected to a linear toothbrush abrasion movement with a rate of 4.5 strokes per second. Brushing abrasion run at a 300-g load with soft-bristled toothbrushes in a temperature of 37 ± 0.5 °C. Brushing was carried out in the presence of a silica-based dentifrice (Colgate Cavity Protection Gel, Colgate-Palmolive Co., São Bernardo do Campo, SP, Brazil)/deionized water suspension (1:3, w/w). Specimens were then rinsed, closing a cycle, which was repeated four more times in that day. Prior to the next 5 cycles, specimens were stored in artificial saliva at 37 ± 1 °C overnight.

Wear measurements

Specimens were carefully cleaned with acetone-soaked cotton pellets in order to remove the nail varnish. Root dentine loss was quantitatively determined with a profilometer (Surfcorder SE-1700, Kosaka, Tokyo, Japan). For profilometric measurements the stylus moved across the sound dentine surfaces, which had been protected by the nail varnish during the experiment, and the dentine which had been subjected to the erosive/abrasive cycles. Profilometer allowed for calculating of the average depth of the specimens relative to the before-protected surface areas. Five scans were performed within 1 mm from the restorationś margin. The average of these measurements was considered as the outcome value for each specimen.

Statistical analysis

Data analysis was accomplished by the SAS 6.11 statistical package at a significance level of $\alpha = 0.05$. After checking whether the assumptions of normality and homocedasticity had been met, data were evaluated by a two-way analysis of variance. *Post hoc* pairwise multiple comparisons were conducted using Tukey's test.

Results

The mean values (standard deviations) and statistical comparisons for wear depth are summarized in Table 2. Two-way ANOVA revealed that the interaction between *restorative system* and *substrate condition* was not statistically significant ($p = 0.5549$). All groups in which abrasion was preceded by erosion showed significantly greater dentine wear than the control groups ($p < 0.0001$). A non-significant difference was found for dentine wear in the vicinity of restorations made with the different restorative systems ($p = 0.8639$).

Discussion

The treatment of advanced root dentine lesions may involve restorative procedures [4, 21, 22]. The selection of the most appropriate restorative material should consider esthetic concerns as well as physical, chemical, adhesive and fluoride-releasing properties [23]. The latter property was hypothesized to have an effect on the degradation process of the dentine around the restoration margins, preventing marginal defects to occur as a consequence of erosive and abrasive attacks. However, in the current study, none of the restorative systems tested could confirm this hypothesis. Explanations may involve the low levels of fluoride released by the materials and/or the high aggressiveness of the erosive/abrasive challenges.

Table 2 Means of wear depth (μm) observed in the vicinity of root dentine restored with fluoridated and non-fluoridated materials following erosive/abrasive episodes

Restorative	Eroded dentine	Uneroded dentine
GIC	4.38 (2.22)^{B}	1.09 (0.62)^{A}
RMGI	4.40 (1.26)^{B}	1.37 (0.94)^{A}
PMRC	4.65 (1.16)^{B}	1.15 (0.75)^{A}
FCRC	3.98 (1.13)^{B}	1.38 (0.65)^{A}
CRC	4.22 (0.97)^{B}	1.14 (0.67)^{A}

Standard deviations are in parentheses

Means followed by different superscripts differ significantly ($\alpha = 0.05$)

Although fluoride has shown to be effective in rehardening eroded dentine [24] and fluoride-releasing restorative materials have been related to the prevention of the secondary root caries [10–12, 14], no differences on the root dentine wear were found adjacent to the fluoride- and non-fluoride-containing restorative materials. It seems that the concentration of the fluoride ions released by the restorative materials, even by the glass-ionomer cement, might not be enough to prevent demineralisation by acidic beverages. This may be explained by the dynamics of erosion progress, which is less susceptible to the benefits of fluoride coming from the restoration than that of caries. Erosion occurs due to a more aggressive attack of dentine by acids, producing relatively deeper lesions in similar periods of time [25]. Caries, on the other hand, progresses through the alternation of episodes of demineralisation by acids from the plaque and remineralisation over a period of time [26]. This specific pattern allows fluoride to act inhibiting demineralisation, promoting remineralisation and interfering with the metabolism of cariogenic bacteria [25]. Moreover, the plaque may act as a fluoride reservoir. Therefore, it can be suggested that fluoride effectiveness in erosion prevention, if any, could be expected to occur at higher concentrations [7, 27]. Further studies checking on the effectiveness and also on the determination of optimal levels of fluoride for the remineralisation response of the eroded dentine may help clarify this statement.

Erosion is more likely to occur in surfaces of easy access to erosive or abrasive agents, which makes easier its progress. As the dentine surface is softened by erosive beverages it becomes more prone to be scratched and lost due to abrasive insults, like toothbrushing [3–5]. The results of this study confirmed this statement and showed the ability of the experimental model to reproduce the development of erosion/abrasion lesions.

The high aggressiveness of the erosive/abrasive challenges in the current model may also explain the inability of the fluoride-containing restorative materials to prevent dentine wear to occur around restorations. Some limitations of the in vitro model used herein may have accelerated the progress of the dentine wear, since bovine dentine is softer than human dentine [28] and the artificial saliva may not have provided a proper lubrication during the abrasive process. Even though the use of human root dentine would be desirable, bovine root dentine has been widely used and accepted in caries [12, 29–31] and erosion studies [5, 9].

Another possible constraint of the present method was that the wear depth may have been measured far away from the restoration's margin, at distances at which potential remineralisability might have been no longer exerted by the fluoride-releasing restoratives. In view of this possibility, further studies are necessary to assess whether the current results hold for precisely known distances from the restoration's margin.

It should be stressed, however, that other aspects was set to resemble the clinical situation. The commercially available lemonade-like carbonated soft drink was chosen due to its high erosive potential, provided by its low pH (ranging from 2.61 to 2.79) and low calcium and fluoride concentration, as compared to other beverages [32]. The use of exposure times of the beverage [33] as well as the repetition of alternated cycles of immersion of the specimens in the acid and artificial saliva were related to the real situation. Although the artificial saliva had some limitation as discussed above it was supposed to reproduce the remineralisation and buffering capacity of the natural saliva. Thus, even considering the restrictions of the experimental model, the results are important to predict the inability of the fluoride-containing restorative materials to prevent root dentine wear in the vicinity of the restorations. Further studies using experimental models closer to the clinical situation, such as the in situ model, are necessary to confirm these findings. Subjects with root surfaces exposed to the oral environment should avoid the high consumption of acidic beverages until the development of effective measures to prevent root dentine wear by erosive/abrasive attacks.

Conclusion

Based on the results found in this study, it is possible to conclude that the fluoride-containing restorative materials tested seems to not inhibit wear of root dentine to occur adjacent to the margins of the restoration.

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References

1. J. H. NUNN, *Eur. J. Oral Sci.* **104** (1996) 156
2. P. A. BRUNTON and E. J. KAY, *Br. Dent. J.* **195** (2003) 237
3. W. B. DAVIS and P. J. WINTER, *Br. Dent. J.* **148** (1980) 253
4. L. C. LEVITCH, J. D. BADER, D. A. SHUGARS and H. O. HEYMANN, *J. Dent.* **22** (1994) 195
5. A. T. HARA, C. P. TURSSI, E. C. TEIXEIRA, M. C. SERRA and J. A. CURY, *Eur. J. Oral Sci.* **111** (2003) 423
6. D. W. BARTLETT, B. G. N. SMITH and R. F. WILSON, *Br. Dent. J.* **176** (1994) 346
7. A. VIEIRA, J. L. RUBEN and M. C. HUYSMANS, *Caries Res.* **39** (2005) 371
8. M. D. LAGERWEIJ, W. BUCHALLA, S. KOHNKE, K. BECKER, Á. M. LENNON and T. ATTIN, *Caries Res.* **40** (2006) 148
9. T. ATTIN, C. ZIRKEL and E. HELLWIG, *Caries Res.* **32** (1998) 344
10. A. T. HARA, C. S. MAGALHAES, M. C. SERRA and A. L. RODRIGUES JR, *J. Dent.* **30** (2002) 205
11. P. DIONYSOPOULOS, N. KOTSANOS, E. KOLINIOTOU-KOUBIA and K. TOLIDIS, *J. Oral Rehabil.* **30** (2003) 1216
12. M. OKUDA, P. N. PEREIRA, T. NIKAIDO and J. TAGAMI, *Am. J. Dent.* **16** (2003) 191
13. Y. TORII, T. ITOTA, M. OKAMOTO, S. NAKABO, M. NAGAMINE and K. INOUE, *Oper. Dent.* **26** (2001) 36
14. L. SAVARINO, L. BRESCHI, M. TEDALDI, G. CIAPETTI, C. TARABUSI, M. GRECO, A. GIUNTI and C. PRATI, *Biomaterials* **25** (2004) 1011
15. J. ARENDS, G. E. H. M. DIJKMAN and A. G. DIJKMAN, *Adv. Dent. Res.* **9** (1995) 367
16. P. KARANTAKIS, M. HELVATJOGLOU-ANTONIADES, S. THEODORIDOU-PAHINI and Y. PAPADOGIANNIS, *Oper. Dent.* **25** (2000) 20
17. J. P. SULJAK and S. HATIBOVIC-KOFMAN, *Quintessence Int.* **27** (1996) 635
18. G. VERMEERSCH, G. LELOUP and J. VREVEN, *J. Oral Rehabil.* **28** (2001) 26
19. A. C. DELBEM and J. A. CURY, *Am. J. Dent.* **15** (2002) 169
20. C. P. TURSSI, C. S. MAGALHÃES, M. C. SERRA and A. L. RODRIGUES JR, *Oper. Dent.* **26** (2001) 576
21. B. T. AMAECHI and S. M. HIGHAM, *J. Dent.* **33** (2005) 243
22. P. LAMBRECHTS, B. Van MEERBEEK, J. PERDIGÃO, S. GLADYS, M. BRAEM and G. VANHERLE, *Eur. J. Oral Sci.* **104** (1996) 229
23. J. O. BURGESS, Am. J. Dent. 8 (1995) 342
24. C. E. FUSHIDA and J. A. CURY, *J. Dent. Res.* **78** (abstr No. 2437) (1999) 410
25. A. T. HARA, M. ANDO, J. A. CURY, M. C. SERRA, C. GONZALEZ-CABEZAS and D. T. ZERO, *Caries Res.* **39** (2005) 134
26. J. D. B. FEATHERSTONE, *Am. J. Dent.* **7** (1994) 271
27. C. GANSS, J. KLIMEK, U. SCHAFFER and T. SPALL, *Caries Res.* **35** (2001) 325
28. A. T. HARA, C. S. QUEIROZ, A. F. PAES LEME, M. C. SERRA and J. A. CURY, *Caries Res.* **37** (2003) 339
29. B. KLONT and J. M. TEN CATE, *Caries Res.* **25** (1991) 46
30. J. M. TEN CATE, J. J. DAMEN and M. J. BUIJS, *Caries Res.* **32** (1998) 141
31. H. MEYER-LUECKEL, J. SCHULTE-MÖNTING and A. M. KIELBASSA, *Oral Dis.* **8** (2002) 192
32. A. LUSSI, T. JAEGGI and S. SCHARER, *Caries Res.* **27** (1993) 387
33. A. MILLWARD, L. SHAW, E. HARRINGTON and A. J. SMITH, *Caries Res.* **31** (1997) 44