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Profile of fluoride release from a nanohybrid composite resin

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Abstract

The aim of this study was to evaluate in vitro the amount and profile of fluoride release from a fluoride-containing nanohybrid composite resin (Tetric® N-Ceram) by direct potentiometry. Thirty specimens (5 mm diameter x 3 mm high; n=10/material) were made of Tetric® N-Ceram, Vitremer® resin-modified glass ionomer cement (RMGIC) (positive control) or Filtek® Z350 nanofill composite resin (negative control). The specimens were stored individually in plastic tubes containing 1 mL of artificial saliva at 37°C, which was daily renewed during 15 days. At each renewal of saliva, the amount of fluoride ions released in the solution was measured using a fluoride ion-selective electrode with ion analyzer, and the values obtained in mV were converted to ppm (μg/mL). Data were analyzed statistically by ANOVA and Tukey's post-hoc test at a significance level of 5%. The results showed that the resins Tetric® N-Ceram and Filtek® Z350 did not release significant amounts of fluoride during the whole period of evaluation (p>0.05). Only Vitremer® released significant amounts of fluoride ions during the 15 days of the experiment, with greater release in first 2 days (p<0.05) and stabilization in the subsequent days (p>0.05). In conclusion, the nanohybrid composite resin Tetric® N-Ceram did not present in vitro fluoride-releasing capacity throughout the 15 days of study.

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Introduction

The effect of fluoride on dental caries prevention appears to be dependent of its constant presence at adequate levels on oral environment, which may interfere in the dynamics of the carious lesion by a decrease in demineralization and increase in remineralization (1,2,3). Since the most common cause of restoration failure in the dental clinic is the occurrence of secondary or recurrent caries around the restoration margins (4,5), the incorporation of fluoride into restorative materials could improve the success of restorative treatment (2,6,7). The intimate contact between the restoration and the tooth margins may also prevent penetration of cariogenic bacteria and acids and facilitate the exchange of fluoride with the hydroxyapatite (8,9). Thus, the use of restorative materials that not only release fluoride, but also have adhesivion to tooth structure has been suggested to prevent recurrent caries around restorations and to promote remineralization of incipient carious lesions on restored surfaces9 or even on adjacent teeth (10).

Although the use of composite resins has increased considerably during the last years, their ability to release fluoride is low or insignificant when compared to other materials, such as glass ionomer cements (GICs) (11,12). Thus, there has been a growing interest in the development of newer composites resins with efficient fluoride release abilities and improved physical and mechanical properties, such as lower polymerization shrinkage (9,13,14). A novel fluoride containing composite resin (Tetric® N-Ceram, Ivoclar Vivadent AG, Schaan - Liechtenstein) was developed based on nanotechnology, aiming to promote low shrinkage and shrinkage stress, high level of radiopacity, low wear and fast polish ability, and high gloss. Tetric® N-Ceram is composed by dimethacrylates and the nano-fillers contain barium glass, copolymers, mixed oxide and ytterbium trifluoride (YbF2), which, according the manufacturer, was added to provide radiopacity, and simultaneously release fluoride. YbF2 is a well know radiopaque agent used for detection of secondary caries or imperfections like air bubbles, but its fluoride ion release ability in association with nanohybrid particles has not been documented. It has been hypothesized that the presence of nanosized fillers offers increased surface area to volume and could provide a quicker release of fluoride (12).

Since the fluoride release efficacy of restorative materials is largely dependent on their composition and setting reaction and nature of fluoride incorporated, we conducted an in vitro study to evaluate hypothesis that the fluoride-containing nanohybrid composite resin (Tetric® N-Ceram) can promote fluoride release compared with a nonfluoride-releasing material (Filtek® Z350) and high fluoride-releasing material (Vitremer®).

Material and Methods

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The materials used in this study were the fluoride-containing nanohybrid composite resin Tetric N-Ceram® (Ivoclar Vivadent AG, Liechtenstein), the RMGIC Vitremer® (3M ESPE, St. Paul, MN, USA), and the nanofill composite resin Filtek Z350® (3M ESPE, St. Paul, MN, USA). The materials composition and manufacturer are summarized (Table 1).

Thirty specimens (5 mm diameter and 3 mm thickness) were prepared from the three materials (n=10) by packing the material into a custom-made polytetrafluoroethylene matrix. The matrix was filled at room temperature (approximately 25°C) and the materials were mixed and light-activated according to the manufacturers' instructions. The mass of each specimen was recorded using a digital precision scale. Vitremer® specimens presented an average mass of 0.143 g, while Tetric N-Ceram® and Filtek Z350® specimens presented an average mass of 0.159 g and 0.140 g, respectively.

The specimens were stored individually in Eppendorf tubes containing 1 mL of artificial saliva (School of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo, SP-Brazil) at 37°C during 15 days and were daily re-immersed in new tubes containing 1 mL of fresh artificial saliva. The amount of fluoride released was studied every 24 hours for 15 days. Each sample was buffered with citrate 0.5 mol/L, pH 5.5, and the fluoride measurements were performed by direct potentiometry with an ion-selective electrode (Orion 2008; Thermo Electron Corporation, Orion Products, Beverly, MA, USA)15. For the measurements, 0.5 mL of artificial saliva were collected from the plastic tubes containing the specimens and homogenized with 0.5 mL of the citrate buffer, and the resulting solution was homogenized again right before the measurement of fluoride release.

Table 1. Restorative materials used in this study.

Material	Manufacturer	Classification
Glass Ionomer Cement Vitremer®	3M Dental Products, St Paul, Minnesota, United States	Glass Ionomer Cement resin-modified type II
Composite Resin Tetric N-Ceram®	Ivoclar Vivadent, São Paulo/SP, Brasil	Nanohybrid Composite Resin
Composite Resin Filtek Z350®	3M Dental Products, St Paul, Minnesota, United States	Nanohybrid Composite Resin

The mean values among the different study groups were compared using one-way ANOVA followed by multiple-range Tukey's HSD test to identify the significant groups (p=0.05) in the GraphPad Prism 4.0 software (GraphPad Software, Inc., San Diego, CA, USA). A significance level of 5% was set for all analyses.

Results

Results were recorded in mV and converted into ppm. For such purpose, a standard curve was prepared using 11 samples of solutions with different fluoride concentrations. From this standard curve, the results in mV were converted to ppm and compared with the values obtained from the standard curve. The values of fluoride release were tabulated as mean ± standard deviations. As shown in Figure 1, the results of the present study showed that, on days 1 and 2, the mean value of fluoride release of Vitremer® was the highest ($p<0.05$) and then fluoride release stabilized in the subsequent days ($p>0.05$). Tetric N-Ceram® and Filtek Z350® showed no detectable amounts of fluoride release throughout the experimental period and presented no statistically significant differences ($p>0.05$) from each other.

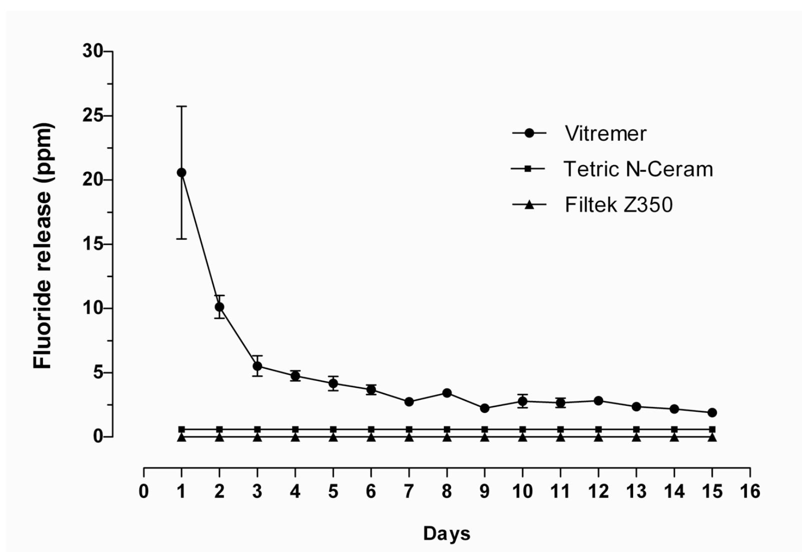

Figure 1. Release of fluoride ions from the three materials at each day of the experiment.

Discussion

The advances in nanotechnology have allowed the development of novel composite resins with improved physical properties, high strength, good wear resistance, and excellent esthetics (13). However, few composites are reported to include in their composition fluoride that may be efficiently released to oral environment by ion exchange or hydrolysis (16). It has been recently suggested that fluoride incorporation into materials containing nano sized fillers could favor its faster release by a higher surface area-to-volume ratio12 Nanocomposites with high strength can be promising materials if they have the capacity to release fluoride, phosphate and calcium ions for the precipitation of fluorapatite (17). However, according to our results, the nanohybrid resin containing YbF_2 fillers (Tetric® N-Ceram) did not present a significant release of fluoride during 15 days of experiment, having similar results to those of the negative control (a conventional hybrid composite). Our results confirmed those of previous studies, which found a constant low level of fluoride released from different composite resins with YbF_2 fillers in their composition (18,19).

The low fluoride release from current commercially available composite resins has been associated with the low amount of fluoride incorporated into these materials as fillers, low solubility of YbF_2 in water (2,10), low water content of the material, and composite resin permeability

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(18). In addition, due to the low solubility of YbF2 in water, it is postulated that the recharging effect of 'fluoride-releasing' composite resins containing this agent may simply be the release of surface-retained fluoride (2). The incorporation of fluoride into composite resins has not shown any beneficial effect in reducing the demineralization of carious lesions in roots when compared with GICs(12,20).

Aiming to solve this problems, novel nanocomposites containing alternative fluoride sources has been developed (13,19,21). One alternative are composite resins containing nanoparticles of calcium phosphates (CaF2), which may release fluoride ions that matched or exceeded reported releases from conventional GICs and RMGICs (21). The mechanical properties and ion release of these composites could be tailored by changing the nanoparticle filler level and reinforcing filler level. These nanocomposites present high release of fluoride, phosphate and calcium ions for precipitation of fluorapatite and inhibition of caries together with good mechanical properties.

The reason for the relatively high fluoride release from these new CaF2-containing nanocomposite is likely the small size and hence the high surface area of the nanoparticles19. Other alternative are experimental composites made of novel fluoride-releasing monomers, such as ternary heavy-metal-fluoride chelates, which have been developed based on the hypothesis that reduction of hydrophilic monomers and improvement of photoinitiators could reduce water sorption and significantly increase the mechanical properties of the composite13. In the study by Ling et al. (2009) (13), one of these experimental composites showed significantly higher fluoride-release and recharge capabilities than commercial fluoride-releasing composites, but physical and mechanical properties were still lower than those of most commercial composite resins.

To date, conventional GICs and RMGICs are still considered the unique materials with higher fluoride-releasing ability and may be clinically indicated to restore decayed non-biting areas in high-caries-risk patients. Several studies have demonstrated the efficacy of these materials as an additional measure for preventing occlusal caries lesions (1,7,10,19,22) by means of their efficient fluoride release ability, which not only may accelerate mineral deposition, but also can change the metabolic activity of the dental plaque.

In the present study, Vitremer®, a RMGIC, was selected as the positive control due to its wide use in restorative dentistry and its broad clinical indication. In fact, we found that Vitremer® had a significant release of fluoride ions, especially in the 1st and 2nd days of evaluation. Our results are in agreement with those of a number of in vitro studies that have also shown higher fluoride release in the first 24 hours 11,23,24), with gradual decrease after 48 hours (12,21). This high initial fluoride release from GICs is due to an acid-base reaction, with the amount of fluoride released proportional to the concentration of fluoride in the material. This is responsible for the phenomenon know as the "burst effect," wherein high amounts of fluoride are released during the first two days (17,20). Fluoride release declines rapidly during the first week and stabilizes after three to four weeks (7,10,22) as a result of the high initial release from the glass particles that are partially dissolved in polyalkenoic acid during the setting reaction (18). An additional property of Vitremer® is its high microbial growth inhibition potential because it retains the true characteristics of conventional GICs, unlike fluoride-containing composite resins, which do not have antibacterial activity (25,26). Caries lesions adjacent to the restoration are likely to take from several months to several years to develop. Thus, fluoride must be continuously released from dental material for long periods to help preventing the development of new caries lesions.

Despite the well demonstrated effects of in vitro fluoride release on the saliva, dental plaque and hard dental tissues, clinical studies have shown controversial results with respect to the actual clinical relevance of fluoride-releasing materials in preventing or inhibiting the secondary caries development compared with materials without capacity of releasing fluoride ions (7). Therefore further research is still needed for the development of novel composites resins with fluoride-release and recharge capabilities, while maintaining their physical, mechanical, and aesthetic properties, which are highly desirable to improve restoration longevity in high-caries-risk patients.

References

1. Effects of Aged Fluoride-containing Restorative Materials on Recurrent Root Caries. Hsu YS, Donly KJ, Drake DR & Wefel JS. Journal of Dental Research. 1998; 77(2) 418-425. PMID: 9465175

2. Fluoride-containing restorative materials. Burke FM, Ray NJ & McConnell RJ. International Dental Journal. 2006; 56(1) 33-43. PMID: 16515011

3. Oral fluoride reservoirs and the prevention of dental caries. Vogel GL. Monographs in Oral Science. 2011; 22 146-157. PMID: 21701197

4. Reasons for replacement of restorations in permanent teeth in general dental practice. Mjor IA, Moorhead JE & Dahl JE. International Dental Journal. 2000; 50(6) 361–366. PMID: 11197194

5. An overview of reasons for the placement and replacement of restorations. Deligeorgi V, Mjor IA & Wilson NH. Primary Dental Care. 2001; 8(1) 5-11. PMID: 11405031

6. Prevention of in vitro secondary caries with an experimental fluoride-exchanging resin. Zimmerman BF, Rawls HR & Querens AE. Journal of Dental Research. 1984; 63(5) 689–692. PMID: 6584474

7. Review on fluoride-releasing restorative materials - Fluoride release and uptake characteristics, antibacterial activity and influence on caries formation. Wiegand A, Buchalla W & Attin T. Dental Materials. 2007; 23(3) 343–362. PMID: 16616773

8. Dependence of in vitro demineralization of apatite and remineralization of dental enamel on fluoride concentration. Featherstone JD, Glena R, Shariati M & Shields CP. Journal of Dental Research. 1990; 69 620-625. PMID: 2312892

9. Fluoride release from restorative materials and its effects on dentin demineralization. . Francci C, Deaton TG, Arnold RR, Swift EJ Jr, Perdigão J, Bawden JW. Journal of Dental Research. 1999; 78(10) 1647-54. PMID: 10520970

10. Effect of fluorides from various restorative materials on remineralization of adjacent tooth: An in vitro study. Baliga MS & Bhat SS. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2010; 28 84-90. PMID: 20660973

11. Fluoride release from glass–ionomer cements, compomers and resin composites. Vermeersch G, Leloup G & Vreven J. Journal of Oral Rehabilitation. 2001; 28 26-32. PMID: 11298906

12. Fluoride release from a new glass-ionomer cement. Neelakantan P, John S, Anand S, Sureshbabu N & Subbarao C. Operative Dentistry. 2011; 36(1) 80-85. PMID: 21488733

13. Novel F-releasing composite with improved mechanical properties. Ling L, X X, Choi GY, Billodeaux D, Guo G & Diwan RM. Journal of Dental Research. 2009; 88(1) 83-88. PMID: 19131323

15. Enamel fluoride concentrations in unerupted third molars and the influence of

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fluoridated water on caries scores. Mestriner W Jr, Polizello AC & Spadaro AC. Caries Research. 1996; 30(1) 83-7. PMID: 8850588

16-Rechargeability of fluoride releasing pit and fissure sealants and restorative resin composites. . Steinmetz MJ, Pruhs RJ, Brooks JC, Dhuru VB & Post AC. American Journal of Dentistry. 1997; 10(1) 36-40. PMID: 9545919

17. Do low-shrink composites reduce polymerization shrinkage effects? Tantbirojn D, Pfeifer CS, Braga RR & Versluis A. Journal of Dental Research. 2011; 90(5) 596-601. PMID: 21282725

18. Strength and fluoride release characteristics of a calcium fluoride based dental nanocomposite. Xu HHK, Moreau JL, Sun L & Chow LC. Journal of Biomaterials. 2008; 29(32) 4261-4267. PMID: 18708252

19. Fluoride release of six restorative materials in water and pH-cycling solution. Garcez RM, Buzalaf RM, Buzalaf MA & Araújo PA. Journal of Applied of Oral Science. 2007; 15(5) 406-411. PMID: 19089169

20. Novel CaF2 Nanocomposite with High Strength and Fluoride Ion Release. Xu HHK, Moreau JL, Sun L & Chow LC. Journal of Dental Research. 2010; 89(7) 739-745. PMID:

21. Elevated Fluoride Products Enhance Remineralization of Advanced Enamel Lesions. Cate JM, Buijs MJ, Chaussain Miller C & Exterkate RAM. Dental Research. 2008; 87(10) 943-947. PMID: 20439933

22. Compressive strength, fluoride release and recharge of fluoride-releasing materials. Xu X & Burgess JO. Biomaterials. 2003; 24(14) 2451-2461. PMID: 12695072

23. Fluoride Release and Recharge from Different Materials Used as Fissure Sealants. Bayrak S, Tunc ES, Aksoy A, Ertas E, Guvenc D & Ozer S. European Journal of Dentistry. 2010; 4(3) 245-250. PMID: 20613911

24. Fluoride release and uptake capacities of fluoride-releasing restorative materials. Attar N & Turgut MD. Operative Dentistry. 2003; 28(4) 395-402. PMID: 12877425

25. Fluoride release and antibacterial activity of selected dental materials. Marczuk-Kolada G, Jakoniuk P, Mystkowska J, Lukzaj-Cepowicz E, Waszkiel D, Dabrowski JR & Leszczynska K. Postępy Higieny i Medycyny Doświadczalnej. 2006; 60 416-420. PMID: 18493226

26. Fluoride content and recharge ability of five glassionomer dental materials. Markovic DL, Petrovic BB & Peric TO. BioMed Central Oral Health. . 2008; 28(8) 21. PMID: 18655734

27. Comparative evaluation of fluoride release from PRG – composites and compomer on application of topical fluoride: An in-vitro study. Dhull KS & Nandlal B. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2009; 27(1) 27-32. PMID: 19414971