The effect of glass ionomer cement Fuji IX on the hard tissues of teeth treated by sparing methods (ART and CMCR)

Marczuk-Kolada G[1]*, Waszkiel D[1], Łuczaj-Cepowicz E[1], Kierklo A[2], Pawińska M[3], Mystkowska J[4]

[1] Department of Paedodontics, Medical University of Białystok, Poland
[2] Department of Dentistry Propaedeutics, Medical University of Białystok, Poland
[3] Department of Conservative Dentistry, Medical University of Białystok, Poland
[4] Faculty of Mechanical Engineering Technical University of Białystok, Poland

Abstract

Purpose: The aim of the study was to assess the effect of glass ionomer fillings Fuji IX on the mineral content of the hard dental tissues of carious teeth treated by sparing methods.

Material and methods: The study material consisted of 4 deciduous teeth lost due to physiological resorption. The teeth had glass ionomer fillings Fuji IX inserted after treatment of caries by means of sparing methods (ART and CMCR). Chemical analysis of enamel and dentin was performed by means of energy dispersive spectroscopy (EDS) with X-ray analysis QUEST system at a distance of 20 um (point C) and 120 um (point D), respectively. The content of the following elements was evaluated in weight percent: oxygen (O), fluoride (F), sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), phosphorus (P), calcium (Ca), strontium (Sr). The Ca/P ratio was calculated. T-student test for pairs, with the level of significance $p<0.05$, was used for statistical analysis of the results.

Results: We found significantly higher levels of fluoride, aluminum and silicon and lower concentrations of calcium and phosphorus in the dentine adjacent to the filling (point C). However, no statistically significant differences were observed in the levels of the elements between these two sites of measurement.

Conclusions: Our results indicate that mineralization of the calcified dentine may involve elements released from glass ionomer cement Fuji IX.

Key words: glass ionomer Fuji IX, mineral analysis, dentin, enamel, BSE imaging.

* CORRESPONDING AUTHOR:
Department of Paedodontics
Medical University of Białystok
ul. Waszygtona 15A, 15-274 Białystok, Poland
e-mail: gkolada@amb.edu.pl (Grażyna Marczuk-Kolada)

Received 24.03.2006 Accepted 30.03.2006

Introduction

Modern approach to the treatment of caries following the principles of minimum intervention recommends tooth sparing preparation [1]. Atraumatic restorative treatment (ART) and chemomechanical caries removal (CMCR) permit preservation of a substantial amount of the hard dental tissue. These techniques have been based on the studies by Fusayama [2] and Massler [3], who in the carious focus distinguished two calcified layers – the outer layer, which is infected, irreversibly denaturated and must be removed, and the inner layer remineralizable. Mineralization of the dentine left in the cavity is likely to occur due to the application of highly bioactive adhesive materials, such as glass ionomer cements.

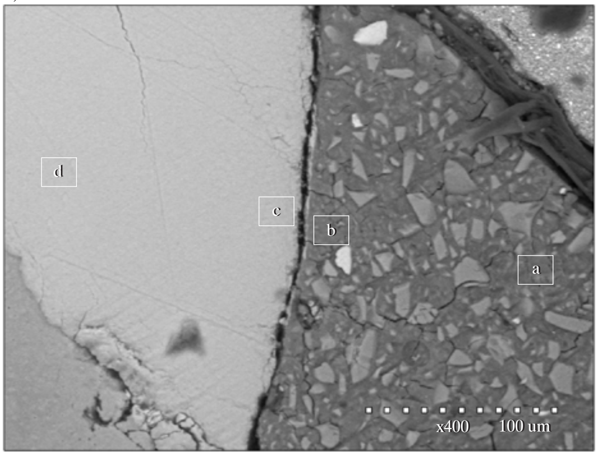
Since their introduction to clinical practice in 1976, glass ionomer cements have gained great popularity due to the release of fluoride ions whose anticariogenic effect is well known. In vitro, these restorative materials have been found to exert an effect on enamel remineralization and to attenuate enamel demineralization in the neighbourhood [7-12]. Some authors have demonstrated antibacterial properties of these cements against cariogenic microorganisms [13-15]. The studies by Forss [16], Wilson [17] and Ngo [18] have shown that not only fluoride but also other ions are released, including aluminum, sodium, silicon, calcium and strontium. Their effect on the hard dental tissues, especially on the partly calcified dentine is little known. Some study results seem to suggest that enamel apatites possess high capacity to exchange ions, and that remineralization does not always involve calcium and phosphorus supplementation [19].

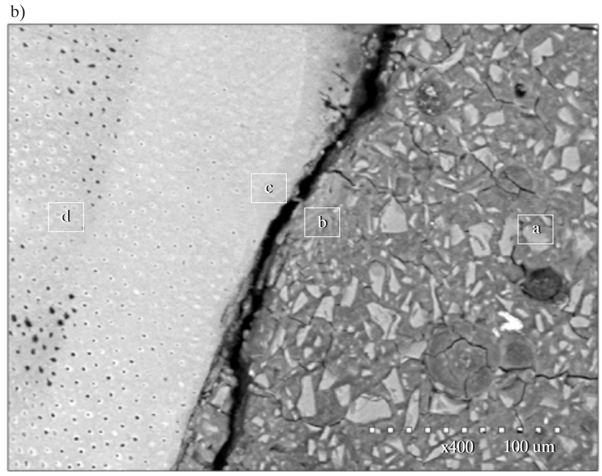
The aim of the study was to assess the effect of glass ionomer cement Fuji IX on the mineral composition of the hard tissues of carious teeth treated by ART and CMCR methods.

Material and methods

The study material consisted of 4 deciduous anterior teeth, lost due to physiological resorption. The teeth had glass iono-

Figure 1. **Microscopic picture of a tooth with Fuji IX ond the borderline of: a) filling – enamel; b) filling dentin**





mer cement restorations Fuji IX, inserted after sparing cavity preparation (2 cavities for each sparing method). After the teeth had been filled, they were left in the mouth for 1-3 years.

Prior to examinations, the teeth were embedded in acrylic resin. Next, their surfaces were grinded on a rotary disc grinder with SIC grinding paper for 10 min and polished. The flat non-dust surfaces obtained in this manner showed distinct borderlines between the enamel, the dentine and the filling. An electron microscope Hitachi S-3000N (Japan) with an X-ray microbe analyzer Thermo Noran (USA) was used for analysis. The surfaces were photographed in BSE at 17kV voltage, at a magnification of 400x. Chemical analysis of enamel and dentin was performed by means of energy dispersive spectroscopy (EDS) with X-ray analysis Quest system on the sample surface area of 291.3 um^2 at a distance of 20 um (point C) and 120 um (point D), respectively – *Fig. 1*. The content of the following elements was assessed in weight percent: oxygen (O), fluoride (F), sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), phosphorus (P), calcium (Ca), strontium (Sr). The Ca/P ratio was also calculated. T-student test for pairs, with the level of significance $p<0.05$, was used for statistical analysis of the results.

Results

The results of mineral analysis of enamel and dentine have been presented in *Tab. 1*. Dentine adjacent to the Fuji IX filling (point C) showed a significantly higher level of fluoride (F), aluminum (Al) and silicon (Si) compared to point D ($p<0.062$, $p<0.001$, $p<0.005$, respectively). The concentrations of calcium (Ca) and phosphorus (P) were significantly lower in the vicinity of the filling in comparison to the dentine at point D ($p<0.02$, $p<0.04$). The strontium content (Sr) was insignificantly higher at the filling. The content of oxygen (O), magnesium (Mg) and sodium (Na) expressed as a percentage of weight was practically the same in both sites of measurement. The elemental analysis of enamel revealed no statistically significant differences between the two sites. The Ca/P ratio approached 2.0 both for enamel and dentine and did not differ significantly between points C and D.

Discussion

Permeation of elements from restorative materials to dental tissues has been reported in several studies. Studies carried out in vitro by Hott et al. [20] and Extercate et al. [21] on bovine teeth revealed elevated fluoride levels in the dentine adjacent to glass ionomer fillings. Tveit et al. [22,23], who in vitro evaluated the absorption of fluoride released from amalgamates enriched with this element, found out that fluoride was better absorbed by dentine than enamel, the finding being consistent with our results. This, according to the authors, is associated with dentine structure, i.e. higher content of the organic part and water and lower crystallization rate. Mucai et al. [24], in vivo confirmed elevated fluoride levels in the dentine adjacent to Vitrabond fillings. Like us, they also found the highest concentration of fluoride directly under the filling, decreasing towards the pulpal surface, which indicates free penetration of this ion inside the dentine. However, conflicting evidence has been provided by Massara et al. [25], who found no presence of F ions in the dentine under the Fuji IX filling. Wessenberg and Hals [26], the Norwegians, assessing the effect of glass ionomer cement ASPA on the mineral composition of enamel and dentine of human teeth in vitro, determined the content of certain elements 1-3 months after the filling insertion. Our results are partly consistent with the data published by these authors. Like them, we found increased fluoride and aluminum levels in the tissues adjacent to glass ionomer cement fillings, the levels being statistically higher in dentine than in enamel. We also revealed similar concentrations of magnesium and sodium in the sites of measurement. Similarly to the Norwegians, we found no significant differences in the levels of Ca and P as well as in the Ca/P ratio in both sites within the enamel. However, some of our results were contradictory to theirs. Unlike them, we observed a rise in the concentration of silicon (Si) in the dentine adja-

Table 1. **The element content in weight percent in the study material**

	Elements	FUJI IX			
		Dentin		Enamel	
		Point C	Point D	Point C	Point D
Mean	Oxygen (O)	40.88	40.43	44.37	41.68
SD		0.68	1.27	4.30	7.44
Mean	Fluoride (F)	0.87*	0.42*	0.62	0.50
SD		0.17	0.13	0.32	0.41
Level of significance		**0.006**			
Mean	Sodium (Na)	1.69	1.35	1.08	0.64
SD		2.28	1.64	0.43	0.15
Mean	Magnesium(Mg)	0.31	0.37	0.27	0.27
SD		0.27	0.25	0.12	0.14
Mean	Aluminium (AL.)	2.84*	1.08*	4.59	0.97
SD		0.44	0.45	5.73	0.30
Level of significance		**0.0001**			
Mean	Silikon (Si)	1.26*	0.82*	3.41	0.64
SD		0.49	0.39	4.43	0.23
Level of significance		**0.005**			
Mean	Strontium (Sr)	1.92	1.37	1.32	1.02
SD		1.42	0.77	0.56	0.50
Mean	Calcium (Ca)	34.11*	36.03*	31.75	36.01
SD		3.53	2.89	9.93	5.77
Level of significance		**0.025**			
Mean	Phosphorus (P)	17.44*	18.15*	15.60	18.27
SD		0.60	0.52	4.61	1.29
Level of significance		**0.040**			
Mean	Ca/P	1.95	1.98	2.03	1.97

cent to the filling. Knychalska-Karwan [27], Pawlicki [28] and Szczepańska [29], who were concerned with the assessment of Ca and P in the enamel of the deciduous teeth reported lower weight percent values of these elements than those obtained in our study. However, it should be remembered that the content of these elements in the hard dental tissues is changeable [30], and according to Pawlicki [28] in the deciduous teeth it undergoes variations with resorption progression. In our analysis, the levels of Ca and P in the dentin adjacent to the filling were significantly lower than those 120 um distant. Wesenberg and Hals obtained contradictory evidence for these elements [26]. However, they examined permanent and not deciduous teeth and in their study ASPA fillings were placed in experimentally formed cavities in the intact dental tissue. Massara et al. [25], who assessed ART, found elevated levels of Ca in the dentine close to Fuji IX, but their study methods differed from ours. The Ca/P ratio obtained in our study is almost identical with those presented by other authors assessing dentine composition after chemomechanical treatment of caries [31,32]. In the current study, the cavities were prepared using manual methods (ART and CMCR). The lower concentrations of calcium and phosphorus in the dentine directly under the filling as compared to the distant sites may suggest the presence of partly demineralized dentine on the cavity floor. This suggestion has also been made by Angker et al. [33].

The significant increase in weight percent values of fluorine, aluminum and silicon in the dentine adjacent to Fuji IX cement may indicate passing of these elements from the filling to the tissue. According to the most recent reports [18,34,35], certain elements such as aluminum, fluorine, strontium and silicon are likely to replace calcium and perhaps phosphorus in apatites. In conclussion the results of the current study seem to confirm the assumption that dentine remineralization may involve elements permeating from the glass ionomer cement Fuji IX into the tissue.

References

1. Tyas MJ, Anusavice KJ, Mount GJ. Minimal intervention dentistry-a review FDI commission projekt 1-97. Int Dent J, 2000; 50: 1-12.
2. Kuboki Y,Ohgushi K, Fusayama T. Collagen biochemistry of the two layers of carious dentin. J Dent Res, 1977; 56: 1233-7.
3. Miller WA, Massler M. Permeability and staining of active and arrested lesion in dentine. Br Dent J,1962; 6: 187-97.
4. Massler M. Changing concepts in the treatment of carious lesions. Br Dent J, 1967; 5: 547-8.
5. Fusayama T. Two layers of carious dentin: diagnosis and treatment. Oper Dent, 1979; 4: 63-70.
6. Mount GJ, Ngo H. Aktywność biologiczna glassjonomerów (szkłojonomerów). Stomat Współcz, 2002; 2: 20-4.
7. Souto M, Donly KJ. Caries inhibibition of glass ionomers. Am J Dent, 1994; 2: 122-4.
8. Hatibovic-Kofman S, Suljak JP, Koch G. Remineralization of natural carious lesions with a glass ionomer cement. Swed Dent J, 1997; 21: 11-7.
9. Papagiannoulis L, Kakaboura A, Eliades G. In vivo vs in vitro anticariogenic behavior of glass-ionomer and resin composite restorative materials. Dent Mater, 2002; 18: 561-69.
10. Ten Cate JM, van Duinen RNB. Hypermineralization of den-

tinal lesions adjacent to glass-ionomer cement restorations. J Dent Res, 1995; 74: 1266-71.

11. Dionysopoulos P, Kotsanos N, Koliniotou-Koubia E, Tolidis K. Inhibition of demineralization in vitro around fluoride releasing materials. J Oral Rehab, 2003; 30: 1216-22.

12. Benelli EM, Serra MC, Rodrigues AL Jr, Cury JA. In situ anticariogenic potential of glass ionomer cement. Caries Res, 1993; 27: 280-4.

13. Kreulen CM, de Soet JJ, Weerhejim KL, van Amerongen WE. In vivo cariostatic effect of resin modified glass ionomer cement and amalgam on dentine. Caries Res, 1997; 31: 384-89.

14. Vermeesch G, Leloup G, Delmee M, Vreven J. Antibacterial activity of glass-ionomer cements, compomers and resin composites: relatioship between acidity and material setting phase. J Oral Rehab, 2005; 32: 368-74.

15. Perez CR, Hirata R, Sergio PP. Evaluation of antimicrobial activity of fluoride-releasing detal materiale using a new in vitro method. Quintessence Int, 2003; 34: 473-77.

16. Forss H. Release of fluoride and other elements from light-cured glass ionomers in neutral and acidic conditions. J Dent Res, 1993; 72: 1257-62.

17. Wilson AD, Groffman DM, Kuhn AT. The release of fluoride and other chemical species from a glass-ionomer cement. Biomaterials, 1985; 6: 431-3.

18. Ngo H, Marino V, Mount GJ. Calcium, strontium aluminium, sodium and fluoride release from four glass ionomer cements. J Dent Res, 1998; 77: Abstr. 75, 641.

19. Mielcarek A, Wojtowicz A, Wierzbicka M, Sikorski K, Mizera J. Ocena strukturalna i mikroanalityczna szkliwa ludzkiego. Stomat Współcz, 1999; 6: 30-4.

20. Hotta M, Li Y, Sekine I. Mineralization in bovine dentin adjacent to glass-ionoimer restorations. J Dent, 2001; 29: 211-5.

21. Exterkate RAM, Damen JJM, Ten Cate JM. Effect of fluoride-releasing filling materials on underlying dentinal lesions on vitro. Caries Res, 2005; 39: 509-13.

22. Tveit AB, Lindh U. Fluoride uptake in enamel and dentin surfaces exposed to a fluoride-containing amlgam in vitro. A proton microprobe analysis. Acta Odontol Scand, 1980; 38: 279-83.

23. Tveit AB, Tötdal B. Fluoride uptake by cavity walls from a fluoride-containing amalgam in vitro. An electron microprobe analysis. Acta Odontol Scand, 1981; 39: 107-13.

24. Mukai M, Ikeda M, Yanagihara Y, Hara G, Kato K, Nakagaki H, Robinson C. Fluoride uptake in dentine from glass-ionomer cement in vivo. Arch Oral Biol, 1993; 38: 1093-8.

25. Massara MLA, Alves JB, Brandão. Atraumatic restorative treatment: clinical, ultrastructural and chemical analysis. Caries Res, 2002; 36: 430-6.

26. Wesenberg G, Hals E. The in vitro effect of a glass ionomer cement on dentine and enamel walls. An electron probe and microradiographic study. J Oral Rehab, 1980; 7: 35-42.

27. Knychalska-Karwan Z, Pawlicki R. Próchnica zębów mlecznych w obrazie morfologicznym w SEM i mikroanalitycznym w mikrosondzie rtg. Czas Stomat, 1999; LH: 8-13.

28. Pawlicki R, Knychalska-Karwan Z. Resorbcja zębów mlecznych. Obrazy morfologiczne oraz zmiany jakościowe i ilościowe składników mineralnych. Mag Stomat, 1994; 6: 7-12.

29. Szczepańska J. Analiza pierwiastków wchodzących w skład szkliwa zębów mlecznych w badaniach in vitro po zastosowaniu preparatów demineralizujących zawierających fluorek sodu i ksylitol. Doniesienie wstępne. Czas Stomat, 1999; LH: 798803.

30. Wong FSL, Andersen P, Fan H, Davis GR. X-ray microtomographic study of mineral concentration distribution in deciduous enamel. Arch Oral Biol, 2004; 49: 37-44.

31. Yip HK, Beeley Ja, Stevenson AG. Mineral content of the dentine remaining after chemomechanical caries removal. Caries Res, 1995; 29: 111-17.

32. Hossain M, Nakamura Y, Tamaki Y, Yamada Y, Jayawardena JA, Matsumoto K. Dentinal composition and Knoop hardness measurements of cavity floor following caries ddentin removal with Carisolv. Oper Dent, 2002; 28: 346-51.

33. Angker L, Nockolds C, Swain MV, Kilpatrick N. Quantitative analysis of the mineral content of sound and carious primary dentine using BSE imaging. Arch Oral Biol, 2004; 49: 99-107.

34. Tanaka T, Maki K, Hayashida Y, Kimura M. Aluminium concentrations in human deciduous enamel and dentin related to dental caries. J Trace Elements Med Biol, 2004; 18: 149-54.

35. Ngo H. Ostatnie osiągnięcia w dziedzinie glassjonomerów. Stomat Współ, 2004; 11: 8-13.