# **Band Cementation Materials: Solubility and Fluoride Release**

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**Purpose:** The aim of this study was to evaluate the solubility and the fluoride release of different materials used for orthodontic band cementation in different solutions and at different times.

**Materials and Methods:** Three materials were selected: Ultra Band-Lok (UBL); RelyX (RLX) and Ketac-Cem (KTC). Sixteen standard samples from each material were prepared, according to the manufacturers' instructions. The samples were stored in two different solutions (n = 8): 0.9% saline solution (pH 7.0) and 0.1 mol/l lactic acid (pH 4.0). The storage solutions were changed after 24 h and after 7, 15 and 30 days. The fluoride release was determined with an ion-specific electrode (Analion). For the solubility evaluation, the formula  $W_{sl} = (m_1 - m_2)/V$  was used to determine the loss of mass. Data were submitted for statistical analysis using the non-parametric Kruskal–Wallis test.

**Results:** With respect to the solubility, immersion in lactic acid increased the solubility when compared with saline solution (P < 0.01). In both the solutions, there were differences among materials (P < 0.01) with the following rankings: UBL < RLX < KTC for lactic acid and UBL < RLX < KTC for saline solution. The ranking of fluoride release was UBL < KTC < RLX. In the two tested solutions, RLX exhibited the highest fluoride release (P < 0.01), whereas KTC showed more fluoride release than that of UBL (P < 0.05). Fluoride release decreased over time and the storage solution influenced the fluoride-releasing capacity of some materials.

**Conclusions:** It was found that fluoride release was influenced by storage solution, materials and immersion time. Materials and storage solution were the significant factors for solubility.

Key words: cementation, fluoride release, orthodontic bands, solubility

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**C**urrently, glass-ionomer cements (GICs), resinmodified glass-ionomer cements (RMGICs) and compomers are available for band cementation

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working time; also, photoactivation improves the early mechanical properties of the material (Ewold-sen and Demke, 2001).

Recently, compomers have been specifically designed for orthodontic purposes. The cure of the material depends on light polymerisation and limited acid–base reaction (McCabe, 1998). These materials have demonstrated a potential to inhibit enamel demineralisation through fluoride release (Creanor et al, 2003; Kuvvetli et al, 2006). *In vitro* study using GICs has shown better antimicrobial properties and higher fluoride release than that of compomers (Gillgrass et al, 1999). Clinically, when used to cement bands, compomers and conventional glass ionomers had similar performances (Millett et al, 2001; Williams et al, 2005), and tensile resistance was also equivalent between compomers and two RMGICs (Aggarwal et al, 2000).

The lixiviation of certain components may impair the mechanical properties of the material (Soderholm, 1983). The marginal penetration of water or acid can cause material degradation, resulting in band failure (Soderholm et al, 1984; Toledano et al, 2006). The cement degradation can also facilitate bacterial penetration, allowing biofilm accumulation that causes the establishment of white spot lesions. The fluoride release from cement materials could help prevent the occurrence of white spot lesions. According to Arends and Rubens (1988), the fluoride is released from GICs as a result of material dissolution and ionic changes, whereas in compomers such a release relies only on ionic changes. Usually, the erosion of the material would be tested in vitro, in which the specimens are immersed in saline or lactic acid solution (Setchell et al, 1985). The comparison of the solubility and the fluoride release from RMGICs and compomers that are used for band cementation is relevant for orthodontists.

The aim of this study was to compare the fluoride release and the solubility of three materials that are used for band cementation in different solutions and at different immersion times, and to test the null hypothesis that the material composition, storage solution and immersion time will not influence the degree of solubility and fluoride release.

## **MATERIALS AND METHODS**

## Material selection and sample preparation

Three materials were selected to be used in this study (Table 1): conventional GIC (KTC –



Sixteen samples for each material were prepared with standard metal matrices. The samples had the following dimensions: diameter, 7 mm; height, 2 mm; surface area, 1.2089 cm<sup>2</sup> and total volume, 76.93 mm<sup>3</sup>. The materials were used following the manufacturers' protocols. The matrix was placed over a glass plaque and then filled with the testing cement. A histological glass slide was placed over it and gently pressed. Excess material was removed using a scalpel. The samples were kept undisturbed for 10 min, before the matrix removal. For RLX and UBL groups, the samples were photoactivated for 40 s, using a light-curing unit XL 3000 (3M ESPE) with an energy > 450 mW/cm<sup>2</sup>.

Each group was randomly divided into two subgroups (n = 8) and these were immersed in two storage solutions: 0.9% saline solution (pH 7.0) and 0.1 mol/I lactic acid (pH 4.0).

# Solubility test

The samples were dried for 30 min on a stove at 70°C and then cooled to room temperature. They were weighed in a digital high precision balance (GEHAKA AG2000, São Paulo, Brazil) to obtain  $m_1$ (initial mass) and then immersed in the storage solutions for 7 days. The samples were then washed with water purified by a Milli-Q<sup>®</sup> ultrapure water purification system (Millipore Corporation, MA, USA) and then placed in a dissector for 22 h at 37°C (±1) and then for 2 h at room temperature  $(23^{\circ}C \pm 1)$ . The samples were weighed until they showed a constant weight, which was  $m_2$  (mass after solubilisation). The solubility degree at 7 days was calculated using the formula:  $W_{sl} = (m_1 - m_2)/V$ . During storage, the samples remained at 37°C (ISO 7489: Dental Glass Polyalkenoate, 1986) and a solubility test was performed using ISO guidelines (ISO 4049: Dentistry - Resin Based Filling Materials, 1988). The storage solutions were changed daily.

## Fluoride release

The samples were stored in both the solutions and analysed for fluoride release after 24 h and after 7, 15 and 30 days; during which the samples were removed from the solution and were washed with Milli-Q water. The cumulative fluoride release was evaluated between time intervals 0 and 24 h; 24 h

Table 1 Materials used in this study						
Products	Classification	Manufacturer	Batch number			
Ultra Band-Lok Reliance Orthodontic Products Ketac-Cem radiopaque	Compomers RMGIC GIC	Reliance Orthodontic Products, Itasca, IL, USA 3M ESPE Dental Products, St. Paul, MN, USA 3M ESPE Dental Products, St. Paul, MN, USA	208160 EBEC – 3415A3 FW0065391			

and 7 days; 7 and 15 days; and 15 and 30 days. An ion analyser Software 2.1.0048 was used for fluoride analysis. This was done using a fluoride ionspecific electrode coupled with a microprocessed potentiometric appliance (Analion, model AN 2000, São Paulo, Brazil). Fluoride values were expressed in parts per million (ppm) and then converted to  $\mu$ g/cm<sup>2</sup>. After sample removal from the storage solution, the solutions were homogenised by shaking and were collected to evaluate the fluoride release at each time period. For each fluoride determination, 9 ml of activated storage solution plus 1 ml of total ionic strength adjustment buffer III (TISAB III) were used and three readings were recorded for each sample. The pots that contain the samples were washed with Milli-Q water and dried with an absorbent paper. New storage solutions were then made and the samples were again immersed. This process was repeated until the final evaluation (30 days).

#### Statistical analysis

As a normal distribution was not found for fluoride release or for solubility, data were submitted for statistical analysis with a non-parametric Kruskal–Wallis test. GMC 8.2 Software (Ribeirão Preto Dental School, University of São Paulo, Brazil) was used for this analysis.

#### RESULTS

#### Solubility

The data in Table 2 present the solubility degree of different materials in both the storage solutions. Storage solutions and materials were the significant factors for solubility (P < 0.001). Increased solubility was observed for materials immersed in lactic acid, when compared with those immersed in saline (P < 0.001).

In saline solution, there were significant differences among all materials (P < 0.001). In the two tested solutions, compomers exhibited the lowest

Table 2 Solubility degree of different materials in be	oth
the storage solutions ( $\mu g/mm^3$ )	

und et a

Groups	Saline s mean (	olution (±SD)	Lactic acid mean (±SD)			
UBL	3.41 (:	3.41 (±1.23)		6.83 (±2.63)		
	А	а	А	b		
RLX	78.65 (:	±6.39)	106.75 (±13.05)			
	С	а	В	b		
KTC	129.50 (:	129.50 (±11.87)		±5.99)		
	D	а	С	b		

Different capital letters in columns indicate significant differences between materials in each storage solution, and different lowercase letters in rows indicate significant differences between each material in both the solutions (non-parametric Kruskal–Wallis test – confidence level (CL) 95%).



**Fig 1** Comparative degree of solubility for different materials in both the storage solutions. UBL, Ultra Band-Lok; RLX, RelyX Luting; KTC, Ketac-Cem.

solubility degree (P < 0.001) and conventional GICs represented higher solubility than RMGICs (P < 0.001). Figure 1 shows that for all materials a higher surface degradation was observed in acid solution.

#### Fluoride release

The mean values of fluoride release ( $\mu$ gF/cm<sup>2</sup>) for different materials in both the solutions and at different time intervals evaluated are exhibited in Table 3.

evaluated (µgF/cm <sup>2</sup> )									
Solutions	Groups	<b>0–24 h</b> 12.5214 (±1.7873)		<b>24 h to 7 days</b> 0.8336 (±0.0150)		<b>7–15 days</b> 0.7876 (±0.0280)		<b>15–30 days</b> 1.3062 (±0.0620)	
Saline	UBL								
solution		В	а	С	С	С	С	В	b
	RLX	47.2767 (	(±1.1151)	9.5249 (±0.9319)		6.3278 (±0.2976)		3.4253 (±0.2031)	
		А	а	А	b	А	С	А	d
	KTC	11.1582 (±0.7874)		2.4766 (±0.1486)		2.3417 (±0.1002)		1.0254 (±	1.0254 (±0.0954)
		В	а	В	b	В	b	В	С
Lactic acid	UBL	13.2830 (±3.5060)		0.8522 (±0.0855)		0.7478 (±0.075)		0.5174 (±	-0.0780)
		С	а	С	b	С	b	С	С
	RLX	39.8672 (±1.2657)		7.7694 (±0.7770)		5.5646 (±0.2801)		2.4590 (±0.0970)	
		А	а	А	b	А	С	А	d
	KTC	23.3802 (±1.5558)		4.5245 (±0.4670)		3.2742 (±0.3509)		1.7396 (±0.0161)	
		В	а	В	b	В	С	В	d

Table 3 The mean value of fluoride release for different materials in both the solutions and at the different time intervals

Different capital letters indicate significant differences between materials in each storage solution and different lowercase letters indicate significant differences between each material in different time intervals (CL 95%).



Fig 2 Fluoride release ( $\mu$ gF/cm<sup>2</sup>) over time for different materials immersed in saline solution. UBL, Ultra Band-Lok; RLX, RelyX Luting; KTC, Ketac-Cem.



Fig 3 Fluoride release ( $\mu$ gF/cm<sup>2</sup>) over time for different materials immersed in lactic acid. UBL, Ultra Band-Lok; RLX, RelyX Luting; KTC, Ketac-Cem.

Table 4 Cumulative fluoride release (0 h to 30 days)
from different materials in both the storage solutions
$(\mu gF/cm^2)$

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Groups		Sa	aline so	lution	Lactic acid		
UBL		15.4488			15.4004		
			В	а	A	а	
RLX			66.554	7	5	5.6602	
			D	b	A	а	
KTC			32.978	4	3	2.9185	
			С	а	А	а	
Different	capital	letters	indicate	significant	differences	between	

indicate significant differences between each material in both the solutions (CL 95%).

The statistical analysis (non-parametric Kruskal– Wallis test) demonstrates that significant differences (P < 0.001) were observed among the materials. In both the solutions, there was a similar ranking of the materials: RMGICs > GICs > compomers. The fluoride release had significantly decreased with ageing (P < 0.001). RMGICs and compomers released more fluoride in saline solution than that in lactic acid. The acid environment has significantly increased the fluoride release of GICs. Figures 2 and 3 are graphical representations of the fluoride release in saline solution and lactic acid, respectively. Both the figures show a significant influence of time and materials on fluoride-release patterns.

The findings from cumulative fluoride release  $(\mu gF/cm^2)$  are given in Table 4. The RMGICs exhibited

the highest (P < 0.001) cumulative release of fluoride in both the solutions. GIC material showed higher cumulative release than that of compomer.

# DISCUSSION

In the present study, two storage solutions were used. The choice of saline was due to its inert characteristic, without the buffering agents present in artificial saliva. In contrast, lactic acid, which is produced in the cariogenic biofilm, plays an important role in the demineralisation process in the oral cavity.

An increased solubility of materials was observed in lactic acid when compared with that of saline solution. This finding could reinforce the deleterious effect of acid produced by bacteria over dental materials placed in the oral cavity. The GICs showed higher solubility than the RMGICs, and minimal solubility was observed for the compomer. In a recent study (Eisenburger et al, 2003), researchers compared the solubility pattern of different dental cements in an acid environment. They observed higher degradation for conventional GIC in comparison to resin cement, which did not exhibit degradation even after 7 days. The main reason in explaining the different solubility patterns observed is the setting reaction of the samples. The conventional GIC has an acid-base reaction, whereas the RMGIC has its initial setting provided by photopolymerisation, followed by acid-base reaction. The compomer material achieves its setting reaction through photopolymerisation. The inclusion of resinous components in the ionomeric materials decreased the solubility and improved the mechanical properties (Burgess et al, 1996; Toledano et al, 2006). In the continuum between the GICs and the resin composites, the compomers are located close to the resin composite and exhibit similar properties. In this research, the compomer demonstrated a very low degree of solubility in saline solution, confirming the high resistance of resinous materials to degradation in the oral cavity (Eisenburger et al, 2003).

It was verified that GICs significantly reduced the demineralisation of enamel *in vitro* (Gorton and Featherstone, 2003). Scientific literature has shown that fluoride from some band cementation materials can inhibit the enamel demineralisation around the cementation (Erickson and Glasspoole, 1995; Glasspoole et al, 2001).

Generally, the studies regarding fluoride release of dental materials show that conventional GICs have similar or superior values compared with



RMGICs, which have superior performance in comparison to compomers (Monteith et al. 1999; Attar and Onen, 2002; Xu and Burgess, 2003). The results of this study demonstrate that the RMGIC has the highest fluoride release, and this result can be corroborated by the previous findings (Dionysopoulos et al, 2003; Pedrini et al, 2003; Hayacibara et al, 2004; Matalon et al, 2005). This fluoride-release pattern for the RMGIC is explained as a consequence of a more homogeneous composition (Hayacibara et al, 2004).

The fluoride release is related to the ionic changes within the oral environment and the acid-base reaction that takes place between the material and the solubility of glass fillers. The conventional GICs have shown greater fluoride release than the compomers (Gillgrass et al, 1999, 2001; Caves et al, 2003; Kuvvetli et al, 2006).

While fluoride release of the GIC is attributed to the chemical composition of the material, the fluoride release of the compomer depends on the aluminium silicate fillers, which can be increased in an acid environment (Ewoldsen and Demke, 2001). In this study, compomers and RMGICs have exhibited more fluoride release in saline solution than in lactic acid. The low fluoride release of the compomer may be due to its proximity to resin composite, instead of the GICs (Itota et al, 1999). It is appropriate to note that a clinical trial is needed to study caries prevention (Eichmiller and Marjenhoff, 1998; Montanaro et al, 2004). Thus, fluoride release from luting agents could be an advantage as an auxiliary method for caries prevention (Donly and Segura, 2002).

The immersion time has significantly influenced the pattern of fluoride release. More fluoride was released in the first period of time evaluated and this value later decreased over time. Several reports in the literature have demonstrated that fluoride is mostly released in the first 24 h to 7 days (Forsten, 1998; Bertacchini et al, 1999; Dionysopoulos et al, 2003; Kuvvetli et al, 2006). If another fluoride source is provided, the glass ionomer materials may serve as a fluoride reservoir and increase the level of fluoride released after the application of one of these sources (gel, dentifrice or solution containing fluoride) (Attar and Onen, 2002; Dionysopoulos et al, 2003; Xu and Burgess, 2003).

The fluoride-releasing capacity has been related to the degree of solubility of the material (Bertacchini et al, 1999). This relationship was not observed in this study for glass ionomeric materials, as conventional GICs had a higher degree of solubility and lower fluoride release than RMGICs. Similarly, other studies found a negative correlation between the mechanical properties and fluoride release or the recharge ability of different fluoride-releasing materials (Xu and Burgess, 2003). In this study, compomer exhibited the lowest degree of solubility and the lowest fluoride release value.

This was an *in vitro* test and the limiting factor was the ability to accurately produce oral cavity conditions. *In situ* or *in vivo* studies are more relevant to demonstrate the real performance of the materials. However, ethical concerns have limited the possibility of these studies. In addition *in vivo* studies are more time-consuming.

The null hypotheses tested in this study were rejected, as materials, storage solutions and immersion times influenced the properties evaluated.

#### CONCLUSIONS

Within the limitations of this study, it can be concluded that:

- 1. the materials tested and the storage solutions have influenced the solubility and the fluoride release
- generally, the immersion in lactic acid increased the solubility degree and the fluoride release when compared with that in the saline solution
- 3. RMGICs and GICs demonstrated higher fluoride release, which decreased with material ageing
- the material with higher resinous composition (compomer) demonstrated the lowest degree of solubility.

#### REFERENCES

- 1. Aggarwal M, Foley TF, Rix D. A comparison of shear-peel band strengths of 5 orthodontic cements. Angle Orthod 2000;70:308–316.
- Anusavice K. Phillips' Science of Dental Materials. Philadelphia: WB Saunders, 2003.
- 3. Arends J, Rubens J. Fluoride release from a composite resin. Quintessence Int 1988;7:513–514.
- Attar N, Onen A. Fluoride release and uptake characteristics of aesthetic restorative materials. J Oral Rehabil 2002;29:791–798.
- Bertacchini SM, Abate PF, Blank A, Baglieto MF, Macchi RL. Solubility and fluoride release in ionomers and compomers. Quintessence Int 1999;30:193–197.
- Burgess JO, Norling BK, Rawls HR, Ong JL. Directly placed esthetic restorative materials – the continuum. Compend Contin Educ Dent 1996;17:731–732, 734 passim; quiz 748.

- Caves GR, Millett DT, Creanor SL, Foye RH, Gilmour WH. Fluoride release from orthodontic band cements – a comparison of two in vitro models. J Dent 2003;31: 19–24.
- Creanor SL, Al-Harthy NS, Gilmour WH, Foye RH, Rogers I, Millett DT. Fluoride release from orthodontic cements – effect of specimen surface area and depth. J Dent 2003;31:25–32.
- 9. DeSchepper EJ, White RR, von der Lehr W. Antibacterial effects of glass ionomers. Am J Dent 1989;2:51–56.
- Dionysopoulos P, Kotsanos N, Pataridou A. Fluoride release and uptake by four new fluoride releasing restorative materials. J Oral Rehabil 2003;30:866–872.
- 11. Donly KJ, Segura A. Fluoride release and caries inhibition associated with a resin-modified glass-ionomer cement at varying fluoride loading doses. Am J Dent 2002;15: 8–10.
- 12. Eichmiller FC, Marjenhoff WA. Fluoride-releasing dental restorative materials. Oper Dent 1998;23:218–228.
- 13. Eisenburger M, Addy M, Rossbach A. Acidic solubility of luting cements. J Dent 2003;31:137–142.
- 14. Erickson RL, Glasspoole EA. Model investigations of caries inhibition by fluoride-releasing dental materials. Adv Dent Res 1995;9:315–323; discussion 324–331.
- 15. Ewoldsen N, Demke RS. A review of orthodontic cements and adhesives. Am J Orthod Dentofacial Orthop 2001;120:45–48.
- 16. Forsten L. Fluoride release and uptake by glass-ionomers and related materials and its clinical effect. Biomaterials 1998;19:503–508.
- 17. Gillgrass TJ, Benington PC, Millett DT, Newell J, Gilmour WH. Modified composite or conventional glass ionomer for band cementation? A comparative clinical trial. Am J Orthod Dentofacial Orthop 2001;120:49–53.
- Gillgrass TJ, Millett DT, Creanor SL, MacKenzie D, Bagg J, Gilmour WH et al. Fluoride release, microbial inhibition and microleakage pattern of two orthodontic band cements. J Dent 1999;27:455–461.
- 19. Glasspoole EA, Erickson RL, Davidson CL. Demineralization of enamel in relation to the fluoride release of materials. Am J Dent 2001;14:8–12.
- Gorton J, Featherstone JD. *In vivo* inhibition of demineralization around orthodontic brackets. Am J Orthod Dentofacial Orthop 2003;123:10–14.
- 21. Hayacibara MF, Ambrozano GM, Cury JA. Simultaneous release of fluoride and aluminum from dental materials in various immersion media. Oper Dent 2004;29:16–22.
- 22. ISO 4049: Dentistry Resin Based Filling Materials. International Organization for Standardization (ISO), 1988.
- 23. ISO 7489: Dental Glass Polyalkenoate. International Organization for Standardization (ISO), 1986:13.
- Itota T, Okamoto M, Sato K, Nakabo S, Nagamine M, Torii Y et al. Release and recharge of fluoride by restorative materials. Dent Mater J 1999;18:347–353.
- 25. Kuvvetli SS, Tuna EB, Cildir SK, Sandalli N, Gencay K. Evaluation of the fluoride release from orthodontic band cements. Am J Dent 2006;19:275–278.
- Matalon S, Slutzky H, Weiss El. Antibacterial properties of 4 orthodontic cements. Am J Orthod Dentofacial Orthop 2005;127:56–63.
- 27. McCabe JF. Resin-modified glass-ionomers. Biomaterials 1998;19:521–527.
- 28. Millett DT, Hallgren A, McCluskey LA, McAuley F, Fornell AC, Love J et al. A clinical retrospective evaluation of 2 orthodontic band cements. Angle Orthod 2001;71:470–476.



- Montanaro L, Campoccia D, Rizzi S, Donati ME, Breschi L, Prati C et al. Evaluation of bacterial adhesion of Streptococcus mutans on dental restorative materials. Biomaterials 2004;25:4457–4463.
- 30. Monteith VL, Millett DT, Creanor SL, Gilmour WH. Fluoride release from orthodontic bonding agents: a comparison of three in vitro models. J Dent 1999;27:53–61.
- 31. Osinaga PW, Grande RH, Ballester RY, Simionato MR, Delgado Rodrigues CR, Muench A. Zinc sulfate addition to glass-ionomer-based cements: influence on physical and antibacterial properties, zinc and fluoride release. Dent Mater 2003;19:212–217.
- 32. Pedrini D, Delbem AC, de Franca JG, Machado Tde M. Fluoride release by restorative materials before and after a topical application of fluoride gel. Pesqui Odontol Bras 2003;17:137–141.
- 33. Setchell DJ, Teo CK, Khun AT. The relative solubilities of four modern glass-ionomer cements. Br Dent J 1985;158:220–222.
- 34. Soderholm KJ. Leaking of fillers in dental composites. J Dent Res 1983;62:126–130.

- Soderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. J Dent Res 1984;63:1248–1254.
- Toledano M, Osorio R, Osorio E, Aguilera FS, Romeo A, de la Higuera B et al. Sorption and solubility testing of orthodontic bonding cements in different solutions. J Biomed Mater Res B Appl Biomater 2006;76: 251–256.
- 37. Weerheijm KL, de Soet JJ, van Amerongen WE, de Graaff J. The effect of glass-ionomer cement on carious dentine: an in vivo study. Caries Res 1993;27:417–423.
- Williams PH, Sherriff M, Ireland AJ. An investigation into the use of two polyacid-modified composite resins (compomers) and a resin-modified glass poly(alkenoate) cement used to retain orthodontic bands. Eur J Orthod 2005;27:245–251.
- 39. Wilson AD, Paddon JM, Crisp S. The hydration of dental cements. J Dent Res 1979;58:1065–1071.
- 40. Xu X, Burgess JO. Compressive strength, fluoride release and recharge of fluoride-releasing materials. Biomaterials 2003;24:2451–2461.