

Orthodontic Cements and Demineralization: An In Vitro Comparative Scanning Electron Microscope Study

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Abstract:

Background: Comparison of the demineralization potential of four luting cements, i.e. zinc phosphate, conventional glass ionomer cement (GIC), resin-modified GIC and acid modified composite resin.

Materials and Methods: This study was conducted on 75 extracted premolar teeth, which were grouped into five, each group containing 15 teeth. Groups were non-banded control, teeth cemented with the above-mentioned cements. These were incubated at 37°C for 30 days in sealable plastic containers, after which the teeth were debanded, cleaned and placed in acid gelatin solution at 37°C for 4 weeks to simulate the cariogenic solution. Then, the teeth were sectioned and examined under scanning electron microscope. The depth of the carious lesions was measured using image analysis with Digimizer software.

Results: The depth of the carious lesions was maximum with non-banded group, followed by zinc phosphate, acid modified composite resin, resin-modified GIC and conventional GIC.

Conclusions: Among the four orthodontic banding cements compared, the enamel demineralization potential is least with conventional GIC, followed by resin-modified GIC, acid modified composite resin and zinc phosphate.

Key Words: Acid gelatin, Acid modified composite resin, Demineralization, Luting, Resin modified glass ionomer cement, Scanning electron microscope

Introduction

Enamel demineralization and caries, commonly correspond with the use of cemented bands and bonded brackets.^{1,2}

Orthodontic bands are believed to cause more enamel demineralization than brackets as they are more difficult to clean due to their posterior position in the mouth, resulting in greater accumulation of plaque.^{3,4} The contributing factors to enamel demineralization include compromised oral hygiene, cement seal breakdown, inadequate band strength, physical properties, cement solubility in oral fluids and the type of the luting cement used. Enamel demineralization can be prevented or reduced by improving patient oral hygiene or using topical fluoride, but these measures depend on patient compliance and therefore are unreliable.⁵ Orthodontic cements most often used are zinc phosphate, zinc polycarboxylate, conventional glass ionomer cement (GIC), resin modified GIC and Acid modified composite resin.

Zinc phosphate since it has been introduced in 1878,⁶ has become the gold standard by which other cements are compared because of its long and well-documented history of clinical use in band cementation.⁴ Zinc polycarboxylate cements, which react chemically with enamel and stainless steel were introduced to the orthodontic specialty in the early 1970. Both the laboratory studies^{6,7} and clinical studies^{8,9} found these cements to be suitable for band cementation.

GICs introduced in 1971 by Wilson and Kent⁴ gain the adhesion from ionic or polar molecular interactions to tooth enamel and dentin as well as to stainless steel, which suggests their suitability as orthodontic luting cements.^{4,6} GICs form a stronger bond with enamel than with stainless steel, resulting in a position of bond failure mainly at the band-cement interface both *in vitro* and *in vivo*.¹⁰ This tends to leave a protective layer of cement over the enamel that may help to prevent demineralization under loose bands.¹¹ The antibacterial activity and fluoride release shown by them have the clinical benefit toward preventing enamel demineralization during orthodontic treatment. It also demonstrates the ability to remineralize enamel.¹²

Resin modified glass ionomer combines the properties of glass ionomers as well as additional strength afforded by its composite resin component.^{12,13} Setting is not only by the acid-base reaction, but also by a photochemical polymerization typical of composite resins.^{1,14} They do release fluoride into the enamel without losing cement strength.

Compomers being used recently are composed of ion leachable glass in polymeric matrix, set by a light cured resin reaction, not an acid base reaction and rely upon water diffusion into the set polymer. As these cements do not adhere chemically to the enamel like GICs, they tend to fail at the cement enamel interface, and consequently greater risk of stagnation areas, micro-leakage and demineralization.¹⁵

The type of cement is one of the important criteria, which influences the amount of enamel demineralization after post-orthodontic debanding, therefore it is important to study and assess the enamel demineralization potential of the orthodontic luting cements using scanning electron microscope (SEM).

Materials and Methods

This study was conducted on 75 extracted premolar teeth for orthodontic purpose from Department of Orthodontics, R.V. Dental College. The teeth were selected, cleaned and stored in demineralized water. Later the teeth were polished with fluoride free dental prophylactic paste to remove any fine debris and rinsed with demineralized water. Teeth which had abnormal morphology, carious, decalcified, damaged and restored teeth were not included in the study.

Band cementation with different luting agents

Stainless steel bands (0.150" × 0.004") were tightly pinched around sixty teeth using band pinching pliers, fitted and seated with good marginal adaptation using a band seater. Non-banded fifteen teeth were used as control. The banded teeth were randomly allocated, cemented as per manufacturer's instructions and grouped accordingly with each group containing fifteen teeth.

The groups were:

- Group A: Non banded teeth – control.
- Group B: Teeth cemented with zinc phosphate cement (Harvard Cement).
- Group C: Teeth cemented with acid modified composite resin (Transbond, 3M Unitek)
- Group D: Teeth cemented with resin-modified GIC (Multicure, 3M Unitek Dental Products).
- Group E: Teeth cemented with conventional GIC (3M Unitek).

Cements were allowed to bench set at uniform ambient temperature. Later, the teeth by their groups, were placed into five sealable plastic containers with demineralized water.

Incubation in the cariogenic solution

The containers were incubated for 30 days at 37°C to simulate the cement dissolution in the oral cavity. After an incubation period, the bands of each tooth were removed with a band removing pliers. The teeth were coated with acid resistant varnish to protect most of the enamel from demineralization,

leaving a small window of enamel (2 mm × 2 mm) on the buccal surface of the tooth which was exposed.

Acidified gelatin solution was prepared, consisting of 17% gelatin, 1 g/l synthetic hydroxyapatite and 0.1% thymol. The pH of the solution was adjusted to 4.3 by adding lactic acid. Then, all teeth in their respective sealable plastic containers were placed in acidified gelatin solution for 28 days to simulate the cariogenic potential. The cariogenic solution was changed every week to minimize the potential fluoride build-up in the solution.

SEM

Later the teeth were removed from the solution, rinsed with deionized water and sectioned with water-cooled diamond disk buccolingually through the center of the exposed enamel.

The sections were examined under SEM (×100 magnification) shown in Figures 1-5. The depth of the carious lesions was

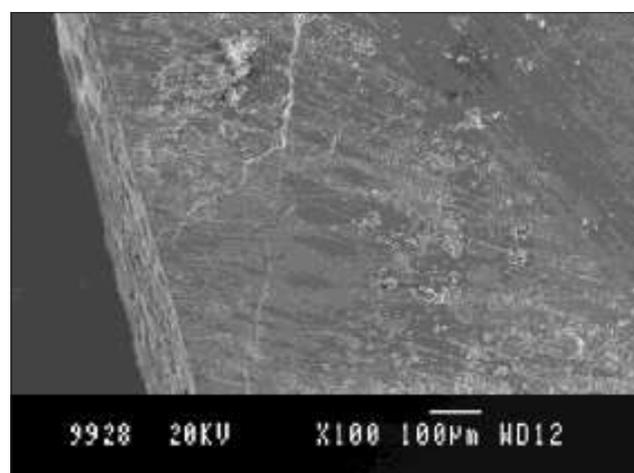


Figure 1: Scanning electron microscope picture of non-banded tooth.

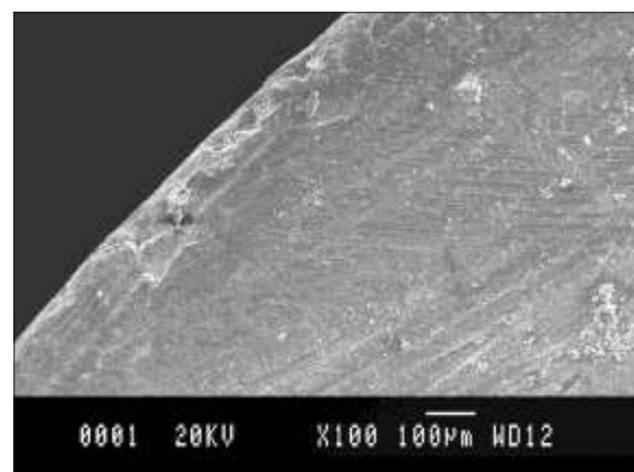


Figure 2: Scanning electron microscope picture of tooth cemented with zinc phosphate.

assessed in microns that were measured from the surface of the tooth to the deepest point of the carious lesion by using image analysis software (Digimizer).

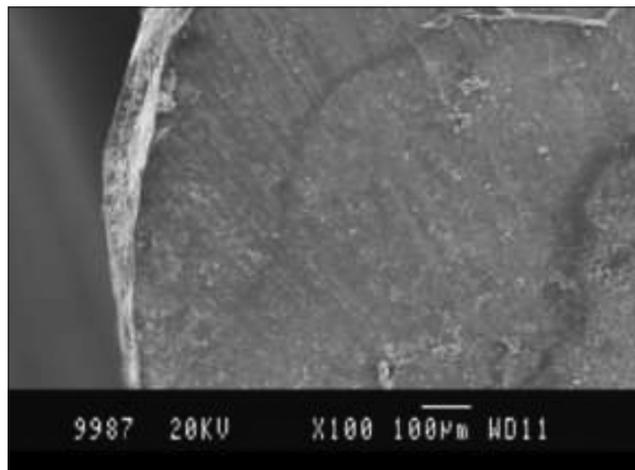


Figure 3: Scanning electron microscope picture of tooth cemented with acid modified glass ionomer cement.

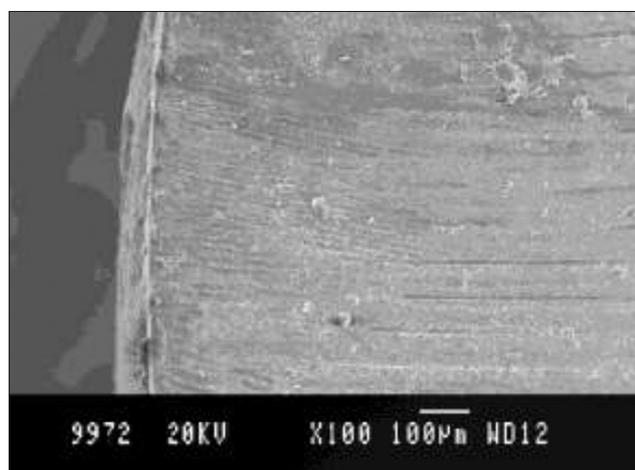


Figure 4: Scanning electron microscope picture of tooth cemented with resin modified glass ionomer cement.

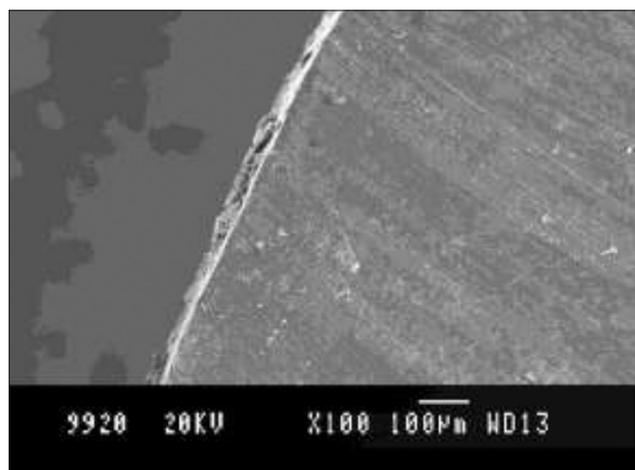


Figure 5: Scanning electron microscope picture of tooth cemented with conventional glass ionomer cement.

Statistical analysis

Analysis of variance has been used to find the significant difference of depth of demineralization between the five groups. The *post-hoc* Tukey test has been used to find the pairwise significance between the groups.

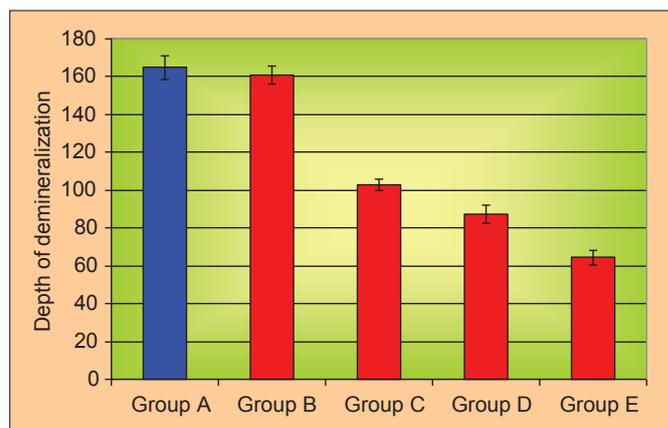
Results

The results of the depth of demineralization potential of the control and above mentioned four orthodontic banding cements in pixels are measured by the Digimizer software from the SEM pictures and they are converted to micrometers and tabulated accordingly shown in Table 1.

It shows that the control and among the four cements, zinc phosphate had the highest demineralization potential while it was least with conventional GIC. This means that among the four orthodontic banding cements assessed, conventional GIC has least demineralization potential, followed by resin-modified GIC, acid modified composite and zinc phosphate shown in Graph 1.

Discussion

The cements and their particular properties assume great significance in prevention of enamel demineralization and possible subsequent caries formation, therefore this study was



Graph 1: Effect on depth of demineralization of four orthodontic banding cements (in micrometers).

Table 1: Effect on depth of demineralization of four orthodontic banding cements (in micrometers).

Groups	Depth of demineralization in micrometers		
	Min-Max	Mean±SD	95% CI
Group A (Control)	156.80-178.10	164.91±6.28	161.43-169.39
Group B (zinc phosphate)	151.90-167.80	160.70±4.89	157.99-163.41
Group C (acid modified composite)	95.40-107.50	102.15±3.11	100.42-103.83
Group D (resin modified GIC)	80.60-93.90	87.30±4.69	84.70-89.89
Group E (conventional GIC)	58.70-71.10	64.41±3.88	62.27-66.55
Significance by one-way ANOVA	F=1375.04; P<0.001**		
GIC: Glass ionomer cement, SD: Standard deviation, CI: Confidence interval			

performed to assess and compare the enamel demineralization potential of the four orthodontic luting cements namely Zinc phosphate cement, conventional GIC, resin-modified GIC and acid modified composite resin using SEM.

The methodology adopted in this study was similar to that of few earlier studies in which the non-banded group served as a control.¹⁶

Non banded teeth (control): The results obtained in the study indicate that non-banded teeth were more prone for demineralization in similarity with earlier studies.¹⁶

Zinc phosphate: The depth of demineralization of Group B (zinc phosphate) was only slightly less than that of the Group A (control). There is no significant difference between the demineralization potential of zinc phosphate and non-banded teeth (control). This infers that the zinc phosphate cement has no characteristic effect on enamel demineralization when compared to the non-banded teeth. This might be attributed to the lack of fluoride release and bacteriostatic property of zinc phosphate cement.¹⁶

Acid modified composite resin: The depth of demineralization of Group C (acid modified composite) is less than that of Group A (non-banded control) and Group B (zinc phosphate). This shows that acid modified composite has significantly less demineralization potential than zinc phosphate cement and non-banded teeth. This could be due to the fluoride-releasing property of the acid modified composite resin as shown by several studies.^{17,18}

Resin modified GIC: The depth of demineralization of Group D (resin-modified GIC) is significantly less than that of non-banded, zinc phosphate and acid modified composite resin.

This could be attributed to the favorable properties of resin-modified GIC which include low solubility in oral fluids, higher compressive and tensile strengths. The resin-modified glass ionomers can chelate via an acid-base reaction to enamel and also do release fluoride into the enamel without losing cement strength, which may add to its less enamel demineralization potential. This was in concurrence with the study done by Timothy Foley et al where resin-modified GIC showed the least mean demineralization depth among the three cements (zinc phosphate, zinc polycarboxylate and resin-modified GIC) tested. The demineralization potential of resin-modified glass ionomer is less than that of acid modified composite resin even though both the cements are fluoride releasing because the resin-modified GIC has an additional bacteriostatic effect.¹⁹ The site of band failure was shown to be at the band-cement interface for resin-modified glass ionomer and enamel-band interface for acid

modified composite resin, hence the teeth cemented with resin modified GIC had a protective cement layer as shown by previous studies.^{13,15}

Conventional GIC: The depth of demineralization of Group E (conventional GIC) was less than all the other groups. This implies that among the four orthodontic banding cements assessed, conventional GIC had significantly least enamel demineralization potential.

This could be due to the ability of conventional GIC to chelate, via an acid-base reaction where adhesion results from ionic or polar molecular interactions to tooth enamel and dentin as shown by earlier studies. This tends to leave a protective layer of cement over the enamel that may help to prevent demineralization under orthodontic bands.¹⁵ The conventional GIC has also shown to have the bacteriostatic effect against the cariogenic strains.¹⁹ Although the resin modified GIC, and acid modified composite resin has fluoride releasing properties, the conventional glass ionomer has shown to have least demineralization potential. This could be attributed to the amount of fluoride release that has shown to be maximum with conventional GIC without loss of any strength and also the longer duration of fluoride release in concurrence with the earlier studies.²⁰ It has also been shown that glass ionomer not only inhibits the demineralization, but also demonstrates the ability to remineralize enamel.²¹

The demineralization potential was highest in relation to Group A (control) followed by Group B, Group C, Group D and Group E in descending order. It means that among the four cements zinc phosphate had the highest demineralization potential while it was least with conventional GIC that suggests that conventional GIC is superior orthodontic banding cement with respect to enamel demineralization potential.

Summary and Conclusions

1. Among the four orthodontic banding cements compared, the enamel demineralization potential is least with conventional GIC, followed by resin-modified GIC, acid modified composite resin and zinc phosphate.
2. It could be suggested that conventional GIC is the superior orthodontic cement with respect to enamel demineralization potential.

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