Medical Communication

Biosci. Biotech. Res. Comm. 10(2): 324-329 (2017)

BBRC
Bioscience Biotechnology Research Communications

Comparative studies on the enamel demineralization of cemented orthodontic bands using four different cements

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ABSTRACT

This study assessed the demineralization depth of the buccal and lingual surfaces of the premolars cemented by zinc phosphate, glass-ionomer, resin-modified glass-ionomer (RMGI) and resin cement to receive orthodontic bands in vitro. In this in vitro experimental trial, 80 intact premolars were collected and after cleaning, they were randomly assigned into 4 groups. Orthodontic bands were cemented to the teeth using zinc phosphate, glass-ionomer, resin-modified glass-ionomer and resin cements. The teeth were stored in the artificial saliva at 37 °C for 7 days to simulate cement solubility in the oral cavity while they were kept in the acidic gelatin solution (gelatin 17%, 1g/L hydroxyapatite, 0.1% thymol, pH=4.3) for in vitro caries stimulations. These procedures were repeated for 4 times (total 8 weeks). After bands removal, the teeth were coated by a nail varnish and only 2 small windows (2×2 mm) in the buccal (which was not under the band and with no contact with cement) and lingual surfaces (under the band with a contact with cement) were exposed. The teeth were kept in 10% methylene blue for 24 hours and after being washed by deionized water, they were sectioned buccolingually. The sections were examined by a microscope in 50x magnification and depth of methylene blue penetrations were calculated. The depths of the demineralization were analyzed by one-sided analysis of variance (ANOVA) and post hot Tukey tests. The demineralization depth in the lingual surfaces using the cements of zinc phosphate, glass-ionomer, resin modified glass- ionomer and resin cement were 17.85 (±11.59), 15.55 (±9.44), 8.55 (±8.04) and 11.8 (±8.88) microns respectively while the values were 26.95 (±6.72), 25.75 (±5.66), 24.35 (±6.77) and 22.65 (±8.19) for the buccal surfaces. Significant differences were found regarding the demineralization depth in the lingual surfaces in different cements (p=0.02), however, the differences were not significant in the buccal

ARTICLE INFORMATION:

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Received 1st April, 2017
Accepted after revision 29th June, 2017
BBRC Print ISSN: 0974-6455
Online ISSN: 2321-4007 CODEN: USA BBRCBA
Thomson Reuters ISI ESC and Crossref Indexed Journal
NAAS Journal Score 2017: 4.31 Cosmos IF : 4.006
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Online Contents Available at: http//www.bbrc.in/

surfaces as a control group. In lingual surfaces, significant differences were observed between zinc phosphate and resin-modified glass-ionomer which was higher for zinc phosphate cement (p=0.02). Resin-modified glass-ionomer showed the best results to prevent enamel demineralization adjacent to the orthodontic bands.

KEY WORDS: DEMINERALIZATION, BANDS, RESIN MODIFIED GLASS-IONOMER, DYE PENETRATION

INTRODUCTION

Enamel demineralization and adhesive bond strength are quite controversial in orthodontic treatments. Although brackets are a certain part of fix orthodontic treatment, more than 85% of the orthodontists use orthodontic bands for molars. If the bond linking the band and tooth fails, decalcification of the tooth surface, unplanned and long visits as well as unsuccessful treatment mechanics will be inevitable (Millett 2003 and Craig 2006). To increase the resistance against occlusal forces, a more stable treatment is applied to use the bands. Hence, it is essential to place an appropriate retention in bands using a mechanical or chemical method. The cement used not only does provide chemical retention, but also it provides a mechanical retention by filling the pores (Kvam 1983, Mosby 2002 and Millett 2009 Kashani et al., 2012 Prabhavathi 2015).

One of the foremost causes of band loosening or why a band has a bond failure is the dissolution of cement in oral cavity. Clinically speaking, the degree of band retention and the extent to which cements dissolve in oral cavity are important since the bands with low retention and cements of high dissolution can accumulate plaque under the bands in a way that enamel decays within three weeks. Therefore, using cements with low dissolution in oral cavity can increase the efficiency of the orthodontic mechanics and reduce caries and microleakage (Norris 1986, Johnson 2000, Millett 2003, Buchalla 2000, Hajmiragha 2008, Sabouhi Prabhavathi 2015).

Since 1878, zinc phosphate cement has been used to cement orthodontic bands. It has a high compressive strength, low tensile strength and it dissolves more quickly adjacent to organic acids (Norris 1986, Johnson 2000, Millett 2003). When cemented orthodontic bands are removed by zinc phosphate, in some cases decalcifications are observed a great deal which can be due to the cement loss between the bands and tooth and a more favorable environment for bacterial activity, (Craig 2006, Buchalla 2000).In addition to the biocompatibility with enamel and dentin, glass-ionomer cement has various cariostatic effects. Fluoride ion activity in these cements can cause remineralization although their bond strength is clinically limited (Pithon 2006 Prabhavathi et al., 2015).

To try to release fluoride and to improve bond strength, resin modified glass-ionomer cements were introduced by Rix (2001). This cement requires moisture because of its specific chemical composition and it can be used in moisture atmospheres as a suitable element to be applied in areas where dry isolation cannot be used. It is chemically bonded to enamel and dentin. Also, it has a similar thermal expansion coefficient compatible with tooth structure (Valente 2002). Resin cements are composites with small filler particles and low filler ensuring there is a thin film thickness. They are much stronger than light-cure glass-ionomers but they cannot expand as light-cure glass-ionomers do. Resin cements can be micromechanically bonded to a prepared enamel, dentin, alloy and ceramics. They are offered in different dyes (O'Brien 2002).The current study aims at comparing the incidences of enamel decalcification of zinc phosphate, glass-ionomer, resin-modified glass-ionomer and resin cement to receive orthodontic bands.

MATERIALS AND METHODS

In this experimental research 80 intact premolars which had no cracks, fractures or restorations were collected and were extracted during a 6-month period for orthodontic treatments. To remove debris, a non-fluoride lotion (13% hypochlorite for 24 hours) was used. After dis-infecting them either in a normal saline or deionized water, they were kept in room temperature (Foley 2002). The teeth were then divided up into 4 groups with 20 in each. The groups were zinc phosphate cements (Hoffmann, Germany), RMGI (GC Fuji, Japan), glass-ionomers cements (GC Fuji, Japan) and Resin Cements (GC Fuji, Japan).

Around the collected teeth, stainless steel orthodontic bands (DENTAURUM,Germany) were installed and were tightly fixed to reduce enamel dissolution. In each band and each group, cement was added in a way that its maker asserted. Care was taken in each group to remove additional cement from the edges of cervical and occlusal bands before they were polymerized so as to they do not affect the results. Afterwards, cements were remained untouched for 2 minutes in 25° C to solidify. (bench set)

After sub-dividing, the teeth were kept in plastic containers and then using an acrylic resin, they were filled high up to normal bones. Only the crowns were exposed and the bands were located a few millimeters higher than acrylic resin. We put the teeth in plastic bags and the following procedures were followed for 4 times (in an 8-week period):

Table 1. Distribution indices of demineralization depth (in microns) in lingual surface of teeth for various cements

Group	Mean	Standard Deviation	Standard Error	95% confidence interval/Low range	95% confidence interval/High range	Minimum	Maximum
Zinc Phosphate	17.85	11.59	2.59	12.43	23.27	0	46.0
Glass-ionomer	15.55	9.44	2.11	11.13	19.97	0	48.0
Resin-modified glass ionomer	8.55	8.04	1.79	4.79	12.31	0	24.0
Resin cement	11.8	8.88	1.99	7.64	15.96	0	26.0

To simulate in vitro caries in oral cavity, the samples were put in an incubator at 37° C in artificial saliva for 7 days. Then, all the teeth were kept in an acidic gelatin solution (17% gelatin,1 g/L hydroxyapatite, 0.1 % thymol, 4/3 pH) in an incubator at 37°C for 7 days (following the recommendations made by Silverstone et al, 1985) (17). They were kept in deionized water subject to demineralization gel.

In the next stage, the teeth were taken out of the acrylic and bands were removed from them. Having removed the leftover cements, the teeth were then cleaned. Following that, they were protected applying nail-varnish. Only two small windows of the enamel (2×2 mm) were exposed. One was beneath the covering band in the lingual surface which was subject to cement and the other outside the covering band in the buccal surface with no touch with the cement. The second one is considered as the control surface for all the molars. In this case, the enamel which was directly connected to the cement and also the enamel which was 2 millimeters far from cement was tested.

The teeth were then put in a 10% methylene blue at 37°C for 24 hours and were washed using deionized water. In this stage, all of them were kept in plastic containers to be prepared for cutting and using epoxy resins, we filled them one millimeter down to the cusps.

The mounted teeth of the epoxy resins were buccolingually cut by a diamond disc with cold water along the line between the buccal and lingual windows. The cuts which were 50 times magnified by a stereomicroscope were then analyzed. Finally, the depth of caries lesions was examined in microns via measuring penetration rate of methylene blue.

We then compared the demineralization depth measures of the caries lesions in different sub-groups through the one-way analysis of variance. In the lingual surfaces of molars, the ANOVA test results were significant so having used Tukey comparisons; we compared them two by two.

RESULTS AND DISCUSSION

The demineralization depth of the caries lesions in lingual surfaces cemented by zinc phosphate, glass-ionomer, resin-modified glass-ionomers and resin cements were 17.85 (± 11.59), 15.55 (±9.44), 8.55 (± 8.04) and 11.8 (± 8.88) microns. (Table 1)

The demineralization depth of the caries lesions in buccal surfaces cemented by zinc phosphate, glass-ionomer, resin-modified glass-ionomers and resin cements were 26.95 (± 6.72), 25.75 (±5.66), 24.35 (± 6.77) and 22.65 (± 8.19) microns. (Table 2)

The results of the one-way ANOVA revealed significant differences in demineralization depth of the caries lesions in lingual surfaces. (p=0.02). On the other hand, the post hot Tukey test aiming at comparing two by two groups showed significant differences between zinc phosphate cements and resin modified glass-ionomer (p=0.02), but in other two-by-two comparisons no significant difference was seen. (Table 3).

In buccal surfaces (control group), there was no significant difference in terms of demineralization depth

Table 2. Distribution indices of demineralization depth (in microns) in buccal surface of teeth for various cements

Group	Mean	Standard Deviation	Standard Error	95% confidence interval/Low Range	95% confidence interval/high range	Minimum	Maximum
Zinc Phosphate	26.95	6.72	1.5	23.8	30.09	9.0	38.0
Glass-ionomer	25.75	5.66	1.26	23.1	28.39	16.0	37.0
Resin-modified glass ionomer	24.35	6.77	1.51	21.18	27.52	15.0	44.0
Resin cement	22.65	8.19	1.83	18.82	26.48	0	40.0

Table 3. The results of various comparisons of cement groups in terms of demineralization depth in lingual surfaces of teeth. (Tukey test)			
First Group	**Second Group**	**Average differences**	**P value**
Zinc Phosphate	Glass ionomer Resin modified glass ionomer Resin cement	2.3 9.3 6.05	0.87 0.02 Significant 0.19
Glass-ionomer	Resin modified glass ionomer Resin cement	7.0 3.75	0.11 0.61
Resin modified glass ionomer	Resin cement	3.25	0. 71

values of caries lesions in using various cements (one-way ANOVA: p=0.24). As there was no significant difference in any of the comparisons, we did not compare the results of the demineralization depth two by two. Obviously, under these circumstances no significant differences will be available among cement groups in terms of demineralization depth values.

On the other hand, the demineralization depth average of caries lesions (Standard deviation ±) in all cements was analyzed and it was 13.44 microns ±) 10.05) for lingual surface of the teeth; whereas in buccal surface it was 24.93 microns (±6.95) According to the results driven from Student t test, significant differences were observed in buccal and lingual surfaces of the molars and in lingual surface it was significantly lower than buccal surface. (p=0.0001)

What makes teeth capable for decalcification and caries when orthodontic bands are applied is that these bands and their connections provide a suitable place for plaque accumulation. It was discovered that 85% of cervical and occlusal margins of orthodontic bands are exposed to caries lesions (Radlanski 2003). Therefore, using cements which can release fluoride can be effective in preventing enamel decalcification. As the findings of this study indicate, significant differences were observed in lingual surfaces in terms of demineralization depth of the caries lesions when zinc phosphate cements and resin modified glass ionomer were used (17.85 and 8.55 microns respectively). In addition, resin modified glass ionomer had the most preventive effects of demineralization. The least capability of preventing demineralization of caries lesions was for zinc phosphate and glass ionomer cements and resin cements respectively. (15.55, 11.8 microns for glass ionomer and resin cements).

In buccal surfaces, which were the control group for all the teeth, there was not any significant difference in demineralization depth of the artificial caries lesions in zinc phosphate, glass ionomer, resin modified glass ionomer and resin cements. Nevertheless, the lowest demineralization depth with an average 22.65 microns was observed for resin cements whereas resin modified glass ionomers, glass ionomer and zinc phosphate followed in ranking respectively, (demineralization depth values: 24.35, 25.75 and 26.95 microns). The variations in demineralization depth in different groups together with high amount of released fluoride from resin modified glass ionomer cements can be indicative of suitable bond strength, high tensile strength and low solubility (Foley 2002, Silverstone 1985, Radlanski 2003).

In this study, the highest values of demineralization depth were observed around the cemented orthodontic bands which used zinc phosphate. This can be due to the fact that zinc phosphate cement did not contain any fluoride and as a result it provided no excessive protection of enamel against acidic attacks of in vitro bacteria. On the other hand, the dissolution of zinc phosphate cement in in vitro cavity can make the teeth vulnerable to caries (Foley 2002).

Also, resin cements have had comparatively more suitable preventive effects of caries around orthodontic bands than glass ionomer cements. Pressure strength and higher tensile strength as well as low solubility and micromechanical bond to the teeth are among the benefits of resin cements compared to glass ionomers. Resin cements are recommended to be used under certain conditions in which RMGIs cannot cause any retention (Weiner 2008).

In 2015 in India, Prabhavathi et al. carried out an in vitro experiment and analyzed demineralization values of orthodontic cements (zinc phosphate, glass ionomer and resin modified glass ionomer cement); and having used acidic gelatin solution, they then stimulated acidic cariogenic conditions and cut the teeth to measure caries lesions by an electron microscope (Prabhavathi et al., 2015). In this research, zinc phosphate cement had the highest demineralization value while the value for glass ionomer was the lowest. These results correspond with the findings obtained from our study about zinc phosphate; nevertheless, RMGI cement of the current study had the minimum demineralization depth and that was different from the recent study.

In an in vitro study conducted in 2014 in India, Hedge et al. (2014) used a similar research protocol and they found out RMGI had the minimum demineralization whereas zinc phosphate had the highest enamel demineralization in banded teeth (Hegde 2014). It can be concluded that the findings taken from this study correspond with the current research. In 2012, in another study in India, Goje et al. investigated the strength against enamel demineralization after banding 4 orthodontic cements in in vitro conditions and they suggested that banded teeth which were cemented by glass ionomer and RMGI had the lowest values followed by zinc poly carboxylate and zinc phosphate (Goje et al. 2012). Same findings could be observed from the current research. Kashani et al., in 2012, investigated the enamel demineralization depth of adjacent cemented orthodontic bands using zinc polycarboxylate, glass ionomer and RMGI in Iran. In their findings, the highest depth was for zinc polycarboxylate; and the best result of preventing caries in orthodontic bands was for RMGI (Kashani 2012).

The results taken from the recent study have been reported in the current research in which RMGI was a more suitable cement to prevent caries lesions. In another research carried out in Canada in 2002, Foley et al. also found out that zinc phosphate had more dye penetration compared to zinc poly carboxylate cements and RMGI. They also reported that RMGI is the best for long-term orthodontic treatment (Foley 2002).As resin modified glass ionomer possesses specific features, researchers consider it as a more suitable cement to prevent caries lesions around and beneath orthodontic bands. Therefore, considering the results of the observations (Foley 2002, Weiner 2008). We can conclude that resin modified glass ionomer could be used as an intermediary for orthodontic banding purposes. However, it is important to consider all the consequences of this replacement including clinical inspections.

It is proven that in the first three days of cementing much more fluoride is released from orthodontic cements. However, after three weeks fluoride release decline considerably (Ogaard 1989). Having said that, it is essential to conduct long term evaluations of demineralization depth of caries lesions after applying orthodontic cements.The lesions of enamel caries which are artificially created have all the histologic characteristics of natural caries and they are successfully applied in in vitro enamel demineralization researches (Casals 2007). Moreover, stimulated enamel caries lesions are prepared in a more homogenous way. As a result, a much more reliable laboratory model is provided to survey demineralization and remineralization depth values. Under these condition the area in enamel in which carries form and has a fixed depth in subsurface, can be used to evaluate remineralization (Queiroz 2008). Generalizing lab research results to oral cavity has its own limitations. First of all, in oral cavity variables such as fluoride weakening by saliva play an important role and hence gaining access to various fluoride products and cleaning them cannot be stimulated in experimental lab studies (Damato 1990). Moreover, in oral cavity conditions, there are variables related to host such as the mineral concentrations of tooth and pellicle or the conditions in which plaque can be formed that can affect demineralization value. The factors related to saliva including salivary flow rate, its composition and buffering capacity can have protective effects in tooth surfaces (Marsh 1999). Increasing the remineralization capability of saliva is also clinically important. As saliva is widely found in oral cavity, the demineralization rate is definitely lower than lab conditions; so more evaluations are recommended in clinical environments and in situ.

CONCLUSION

It can be concluded that using resin modified glass ionomer has had the best results in preventing enamel demineralization under orthodontic bands.

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