Comparative Study of Amorphous Calcium Phosphate-containing Orthodontic Composite and Conventional Orthodontic Adhesive on Enamel Demineralization around Orthodontic Brackets – An in vivo Study

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ABSTRACT

Introduction: One of the most difficult problems in orthodontic treatment with fixed appliances is enamel demineralization around the brackets. This iatrogenically caused white spot lesions leads to poor esthetics; and in severe cases it may need restorative treatment.

Objective: To evaluate *in vivo* effect of Amorphous Calcium Phosphate (ACP)-containing orthodontic composite on enamel demineralization around orthodontic brackets, and to compare it with the conventional resin based orthodontic composite.

Materials & Method: 20 orthodontic patients planned for four first premolars extraction were selected for the study. All first premolars were bonded with Aegis Ortho, an ACP-containing orthodontic composite (experimental group), and Transbond XT, a resin-based orthodontic composite (control group). After 45 days teeth were extracted, sectioned for the microhardness group and evaluated by superficial-microhardness analysis and stereomicroscopic study. Unpaired t-test and analysis of variance (ANOVA) test was performed.

Result: The ANOVA showed statistically significant differences for position, material, depth, and their interactions (p <0.001). The multiple comparison test showed that the ACP-containing orthodontic composite was significantly more efficient than the conventional composite, reducing enamel demineralization in almost all evaluations (p <0.001). The stereomicroscopic examinations showed a lesser extent of demineralization around orthodontic brackets for the ACP-containing orthodontic composite group.

Conclusion: ACP-containing orthodontic composite for bonding orthodontic brackets successfully inhibited demineralization, which was localized to the area around the brackets.

Key words: amorphous calcium phosphate, area of demineralization, conventional composite, white spot lesion

INTRODUCTION

Introduction of simplified bonding procedures has improved the efficiency of clinical practice in orthodontics. However, one of the most difficult problems in orthodontic treatment with fixed appliances is enamel demineralization and formation of white spot lesions around the brackets. The bands, brackets and other various orthodontic appliances make patient's dental hygiene more difficult and accumulation of plaque easier. In orthodontically treated cases this iatrogenically caused white spot lesions lead to poor esthetics and in severe cases it may need restorative treatment.

Study by Bloom *et al*[1] documented significant increase in oral bacteria during orthodontic treatment. The rate of demineralization in orthodontic patients was higher than those without orthodontic treatment.[2] The prevalence of demineralization in orthodontic patients has been reported between 2% to 97% by Mizrahi[2] and Gorelick *et al*.[3]

Zachrisson and Zachrisson[4] stated that, although bonding offers better access for cleaning than banding, it does not necessarily guarantee better oral hygiene and improved gingival condition, especially if excess adhesive extends beyond the bracket base. Also, the protection against

interproximal caries provided by well-countoured cemented bands is absent.

Schumacher *et al*[5] developed biologically active restorative materials that would stimulate the repair of tooth structure through the release of cavity-fighting components including calcium and phosphate. This material contains amorphous calcium phosphate (ACP) as bioactive filler encapsulated in a polymer binder, which has both preventive and restorative properties that justify its use in dental cements, sealants, composites and, more recently orthodontic bracket adhesives.

The present study attempts to evaluate and compare the efficiency of ACP releasing bonding agent (Aegis Ortho) on microhardness and surface demineralization of enamel adjacent to orthodontic brackets with conventional bonding agent (Transbond XT). Thus the aim of this study was to evaluate *in vivo* effect of ACP-containing orthodontic composite on enamel demineralization around orthodontic brackets, and to compare it with conventional resin based orthodontic composite.

The objective of the study were to evaluate and compare the microhardness of enamel around orthodontic brackets using ACP-containing orthodontic composite and Transbond XT composite at 0 µm, 100 µm and 200 µm distance from the brackets, both occlusally and cervically at 10 µm and 20 µm depth. And, to assess and compare the extent of surface enamel demineralization around the orthodontic brackets, with ACP-containing orthodontic composite and Transbond XT composite using stereomicroscope.

MATERIALS AND METHOD

A total of twenty orthodontic patients from Department of Orthodontics, Bharati Vidyapeeth Dental College & Hospital, Pune, who were planned to have four first premolars extractions for orthodontic purpose, were selected for the study. Nature of the study was explained and their written consent were obtained.

Eighty first premolar teeth were used for the study. Inclusion criteria were: 1) maxillary and mandibular first premolars to be extracted as a part of treatment protocol, 2) subjects in the permanent dentition stage with all first premolars erupted completely, and 3) absence of any white spot lesions, caries, fluorosis, fracture, restoration, stain or morphological and developmental defect in upper and lower premolars.

Materials used in the study were: ACP-containing light cure orthodontic composite (Aegis Ortho - Bosworth Co. Illinois), Transbond XT composite, Etchant (37% Phosphoric acid), Liquid primer, Microhardness tester (Reichert Austria, Sr. No. 363798) (Figure 1), and Stereomicroscope with Image Analysis System (Figure 2).

Preparation of the tooth: All four first premolars were polished washed and dried properly. This was followed by isolation, surface conditioning using 37% phosphoric acid gel, rinsed thoroughly with water and air dried. A thin layer of primer was painted on the etched surface.

Bonding of the bracket: A split mouth design was used, where the oral cavity was divided into right and left halves. On the right side i.e. experimental side; upper and lower first premolars were bonded with stainless steel brackets using ACP-containing adhesive. On the left side i.e. control side; brackets were bonded using resin based composite (Transbond XT). The subjects were asked to keep their usual habits, instructed not to use any antibacterial mouthwash, continue eating normal diet avoiding hard and sticky substance and instructed to report after 45 days.

Extraction of teeth: After 45 days the brackets were removed and excess material remaining on the tooth surface was left untouched. The teeth were extracted on the same day without disturbing the buccal surface and stored in a refrigerator in boxes containing gauze dampened with distilled water of pH 7.0, until the analysis was done.

Samples of extracted teeth were divided into two groups (Group I and Group II) each consisting of 40 teeth, which were further subdivided into sub group Ex and sub group C.

Group I: Samples used for microhardness analysis

- Sub group Ex (ACP-containing orthodontic composite) - Consisted of 20 samples
- Sub group C (Transbond XT composite) - Consisted of 20 samples

Group II: Samples used for stereomicroscopic study - Consisted of 40 samples
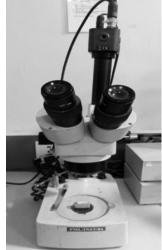

Figure 1: Microhardness tester

Figure 2: Stereomicroscope with Image Analysis System

Figure 3a: Samples prepared for microhardness analysis

Figure 3b: Magnified view of the samples

Figure 4: Diagrammatic representation of positions and depth of indentations

Laboratory Procedures & Analyses

Preparation of Group I samples for microharhness analysis:
The teeth crowns were hemi-sectioned vertically into mesial and distal halves, leaving a crown and root in each half. From each half, the roots were removed 2 mm apical to the CEJ, crown portion was preserved and embedded in self-curing acrylic leaving the cut face exposed. Lapping/final polishing was done on the lapping cloth with alumina powder in suspension and thus the 40 specimens were ready for microhardness analysis (Figure 3).

Microhardness Analysis: Twelve indentations were made in each half crown: A) 0μm (edge of the bracket), 100 μm and 200 μm away from the bracket both occlusally and cervically. B) Depth of 10μm and 20 μm each from the external surface of the enamel at the 6 positions (Figure 4). The samples were subjected to a load of 0.1Kg (1 Newton) for 60 seconds and the values of microhardness numbers at these positions and depths were recorded (Vicker's Hardness – HV).

Preparation of Group II samples for stereomicroscopic examination:

The teeth were mounted on acrylic block with their buccal surfaces exposed, and observed under stereomicroscope with maximum illumination at 10X magnification. The distance between edge of the adhesive on the enamel surface and the border of demineralization zone was viewed on the computer screen; which were measured in micrometers.
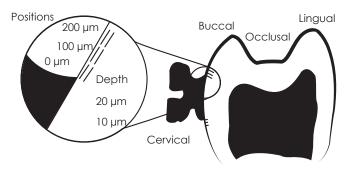
Unpaired t-Test was used to carry out the intra- and inter-group comparisons. Analysis of variance (ANOVA) was used to compare the material hardness at various depths from the enamel surface (10μm and 20μm), positions (on the buccal surface in occlusal and cervical regions at 0, 100 and 200μm from the brackets) and their interactions. The statistically significance level was set at $p < 0.05$ level.
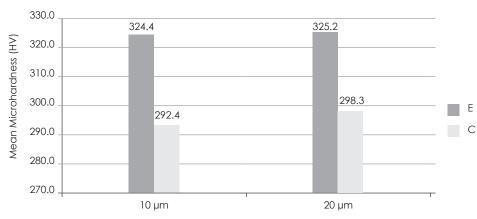
RESULT

Cross-sectional microhardness test was conducted for the selected samples, as a strong co-relation existed between microhardness score and mineral loss from the enamel. Stereomicroscope study was done to evaluate the extent of surface area of demineralization of enamel.

Microhardness Analysis Result

The interaction between depth and material on enamel showed greater mineral loss with Transbond XT (lower enamel hardness value) as compared to ACP-containing composite at both depths. The mean value at 10μm depth was 324.43±27.96 HV and 292.43±34.26 HV, and at 20μm depth the values were 325.26±28.79 HV and 298.32±28.72 HV for ACP-containing orthodontic composite group and Transbond XT composite group respectively (Graph 1).

It was observed that the microhardness value of ACP-containing composite was significantly higher than microhardness of Transbond XT composite (Table 1).

Graph 1: Comparison of microhardness of ACP-containing composite (E) and Transbond XT composite (C) at 10μm.

Greater mineral loss was observed at the cervical region as compared to the occlusal region at 10μm depth, as seen in Graph 2(a) and 2(b).
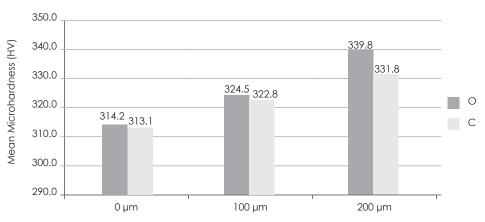
Microhardness value of ACP-containing composite was significantly higher than Transbond XT composite (Table 2).
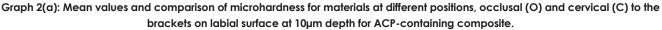
Greater mineral loss was observed at the cervical region as compared to the occlusal region at 20μm depth, as seen in Graph 3(a) and 3(b).
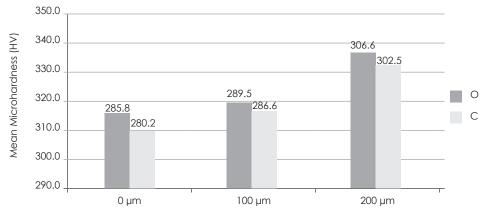
Table 1: Mean microhardness comparison (ANOVA) between ACP-containing composite and Transbond XT composite at different positions, occlusal and cervical to the brackets at 10μm depth.

Depth from enamel surface	ACP-containing composite		Transbond XT composite		p-value
	Mean (HV)	SD	Mean (HV)	SD	
Occlusal					
0 μm	314.275	33.0572	285.815	18.6237	0.000*
100 μm	324.55	28.5362	289.632	27.2748	0.001*
200 μm	339.850	22.8756	306.632	19.7014	0.000*
Cervical					
0 μm	313.190	29.0486	280.211	34.6809	0.011*
100 μm	322.875	24.3278	286.684	54.7155	0.008*
200 μm	331.850	21.8975	302.579	32.0455	0.001*

Significant at $p < 0.05$

Graph 2(a): Mean values and comparison of microhardness for materials at different positions, occlusal (O) and cervical (C) to the brackets on labial surface at 10μm depth for ACP-containing composite.

Graph 2(b): Mean values and comparison of microhardness for materials at different positions, occlusal (O) and cervical (C) to the brackets on labial surface at 10μm depth for Trandbond XT composite.
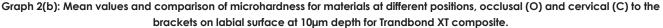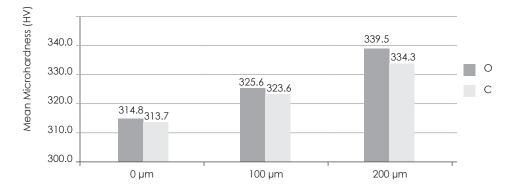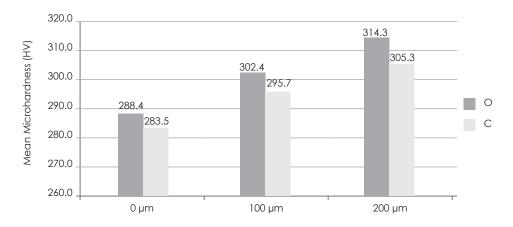
Table 2: Mean microhardness comparison (ANOVA) between ACP-containing composite and Transbond XT composite at different positions, occlusal and cervical to the brackets at 20μm depth

Depth from enamel surface	ACP-containing composite)		Transbond XT composite		p-value
	Mean (HV)	SD	Mean (HV)	SD	
Occlusal					
0 µm	314.80	27.947	288.47	17.605	0.000*
100 µm	325.60	25.339	302.42	21.060	0.000*
200 µm	339.50	23.989	314.32	21.549	0.000*
Cervical					
0 µm	313.70	29.475	283.58	33.547	0.017*
100 µm	323.65	36.196	295.79	34.440	0.069
200 µm	334.30	21.382	305.32	31.168	0.005*

Significant at p<0.05

Graph 3(a): Mean values and comparison of microhardness for materials at different positions, occlusal (O) and cervical (C) to the brackets on labial surface at 20 µm depth for ACP-containing composite.

Graph 3(b): Mean values and comparison of microhardness for materials at different positions, occlusal (O) and cervical (C) to the brackets on labial surface at 20 µm depth for Trandbond XT composite.

Surface Demineralization Result – Stereomicroscopic Study

Smaller area of demineralization was seen in samples where ACP-containing composite was used as compared to Transbond XT composite. The result was statistically significant (Table 3).

Table 3: Mean values and comparison of surface demineralization adjacent to orthodontic brackets between ACP-containing composite and Transbond XT composite.

Group	Number (N)	Mean (μm)	SD	*p*-value
ACP-containing composite	20	88.125	13.675	0.000*
Transbond XT Composite	20	133.985	19.112	

* Significant at p<0.05

DISCUSSION

According to Ogaard,[6] demineralization of enamel surrounding the orthodontic brackets is a common complication and a clinical problem during and after orthodontic treatment. It is a major element of risk to patients when considering the risk-benefit balance of orthodontic treatment.

A study using visual examination of pictures before and after orthodontic treatment reported demineralization of maxillary anterior teeth to be 77%.[7] In another study by Boersma *et al*;[8] the prevalence of WSL in orthodontic patients at debonding was reported as high as 97%. Therefore, it is important for clinicians to develop preventive measures as soon as appliances are placed.

ACP-filled composite resins and orthodontic adhesives developed by Schumacher *et al*[5] have shown to recover 71% of the lost mineral content of decalcified teeth.[9] According to Skrtic *et al*;[10] calcium and phosphate ions released from ACP-containing composites, especially in response to the change in oral environment caused by bacterial plaque or acidic foods can be deposited into the tooth structures as an apatite mineral, which is similar to the hydroxyapatite found naturally in teeth.

In the present study, the mean microhardness was tested between the depth and materials for the enamel around orthodontic brackets, at 10μm and 20μm depth from the enamel surface (Table 1). Significant differences were found between the two tested composites at a depth of 10 and 20μm from the enamel surface.

The depth of the lesions (10 and 20μm) was similar to the results seen in previous the studies conducted by O'Reilly *et al*[11] and Pascotto *et al*.[12] However, the depth of lesions was not in accordance with the reports of Moura *et al*,[13] which showed lesion depth up to 70μm from the enamel surface. This could be attributed to the experimental model used which allowed more plaque accumulation and impaired its removal by tooth brushing.

Mean microhardness comparison between the two materials showed that there was significant difference in enamel loss at different positions (0, 100 and 200μm) at both occlusal and cervical to the base of the bracket. Teeth bonded with ACP-containing composite had significantly lesser amount of mineral loss (higher mean microhardness value - 324.43±27.96 HV and 325.26±27.79 HV at 10 and 20μm depth, respectively) as compared to regular Transbond XT composite. Studies conducted by Caldwell *et al*[14] and Craig *et al*[15] showed the mean microhardness value of healthy untreated teeth with intact enamel was 372 HV (380 KHN) and 336 HV (343±23 KHN) respectively. The microhardness of teeth bonded with ACP-containing orthodontic composite was comparable to the hardness of intact enamel when compared to Transbond XT composite. This effect of ACP-containing orthodontic composite can be attributed to the calcium and phosphate-releasing ability of the material when submitted to cariogenic challenges. Similar results were also seen in a study conducted by Uysal *et al*,[16] where the mean microhardness of enamel was greater for those teeth where brackets had been bonded using the ACP-containing composite in comparison to conventional resin-based orthodontic composite.

Amasyali *et al*[17] compared the efficacy of ACP-containing orthodontic composite, resin-modified GIC and resin based orthodontic composite on enamel demineralization adjacent to orthodontic brackets and evaluated it by a new laser fluorescence device. The ACP-containing orthodontic composite provided the highest reductions in enamel demineralization when compared to the control. An *in vitro* and *in vivo* study conducted by Koyuturk *et al*[18] also showed significant reduction in enamel mineral loss and white spot formation with the use of a CPP-ACP as a topical coating around orthodontic brackets.

On comparison of mean microhardness values for the two composites, occlusal and cervical to the base of the bracket; it was observed that the extent of demineralization was greater (lower microhardness value) in the cervical region, at both depths as seen in Table 2. Comparison of the mean microhardness values by ANOVA test for ACP-containing composite and Transbond XT composite at all 3 positions (0, 100 and 200μm) at the occlusal region of the bracket at both depths showed that there was no significant difference. However, ANOVA comparison at the cervical region of the

bracket showed significant difference for various positions at 10μm depth (*p*-value 0.006) and 20μm depth (p-value 0.027). This difference in the mean microhardness was due to greater dental plaque accumulation and the patient's difficulty in cleaning the cervical area. Similar to the CPP-ACP containing materials, the effect of ACP-containing orthodontic composite occurs on the tooth surface where the patient has difficulty in cleaning dental plaque by brushing. This effect can be attributed to the calcium and phosphate-releasing ability of this orthodontic composite when submitted to cariogenic challenges.[5] A study by Pascotto *et al*[12] showed similar results of reduced enamel hardness around the composite resin in the cervical region of the bracket compared to that in the occlusal area.

In the present study, a significant difference in demineralization inhibition was observed between ACP-containing composite and Transbond XT composite when the samples were observed under stereomicroscope. Transbond XT composite had a greater amount of mean demineralization zone (133.98μm) in comparison to ACP-containing composite (88.12μm). Mean difference was found to be significant. The distance between the edge of adhesive on the enamel surface and border of the demineralised zone was longer for the control group, suggestive of greater area/distance of demineralization. Similar effects of ACP-containing composite was seen on enamel demineralization in a study conducted by Uysal *et al*.[17]

CONCLUSION

Teeth bonded with ACP-containing material are significantly more resistant to demineralization than those bonded with the regular Transbond XT composite even in patients known for high caries risk. ACP-containing orthodontic composite significantly reduces enamel mineral loss around orthodontic brackets in patients' mouth as compared to Transbond XT composites over an experimental period of 45 days.

Thus ACP-containing composite is a recent advancement in orthodontics which can be used in routine clinical practice thereby helping the clinicians in reducing demineralization around the orthodontic brackets; improving the overall quality and end results of orthodontic treatment.

OJN

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