In vivo effect of a fluoride releasing adhesive on inhibition of enamel demineralization around orthodontic brackets

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Abstract

Objective: The purpose of the present study was to evaluate the in vivo effects of the fluoride releasing Transbond™ Plus Color Change Adhesive in reducing enamel demineralization around orthodontic brackets and compare it with non-fluoride releasing Transbond™ XT.

Materials and methods: 20 patients were divided into 2 groups. Brackets were bonded with Transbon-Plus and Transbond-XT in group I & II respectively. After 60 days, teeth were extracted. Buccal surfaces were examined with SEM. Buccolingual cross-sections were examined with SEM and EDX. Comparisons of mineral contents were performed with student t-test.

Results: SEM of group I revealed almost normal topographic features of enamel. Globules of calcium fluoride like material were detected over enamel. Group II revealed roughened enamel surface with areas of enamel erosion. EDX showed higher levels of calcium and fluoride in Transbond™ Plus group than in Transbond™ XT group.

Conclusion: SEM observation and EDX examination showed that the fluoride releasing adhesive (Transbond™ Plus Color Change Adhesive) resulted in reduction of enamel demineralization around the bracket, when compared with conventional adhesive (Transbond™ XT).

Keywords: Demineralization; Fluoride releasing adhesive; Remineralization; Scanning electron microscope; Energy dispersive x-ray microanalysis

1. Introduction

Despite advances in orthodontic materials and techniques in recent years, orthodontic patients are at increased risk of developing clinically detectable areas of decalcification as a consequence of plaque accumulation around orthodontics attachments. This may progress into frank caries.

An increase in white spot lesions has been reported in 50% of patients after orthodontic treatment [1]. They found that decalcification is caused by ineffective oral hygiene and retention of bacterial plaque for an extended period of time on the enamel surface.

Fluoride administration has been proposed as a method of reducing enamel susceptibility to decalcification [4]. The fact that fluoride can be integrated into the crystalline lattice of dental enamel resulting in a structure that is more resistant to the onset of...
dissolution provides the scientific basis for its use in caries prevention. When fluoride ions are incorporated into the surface of enamel, it forms a fluoroapatite crystal structure that has lower solubility in the oral environment compared with hydroxyapatite. Fluoroapatite helps in reducing tooth decay by remineralization of small decalcified areas and reduction in the formation of new lesions [5,6].

Decalcification may be reduced in orthodontic patients by employing a meticulous oral hygiene program including the use of fluoride [7].

Various methods of administering fluoride during orthodontic treatment have been used, including toothpastes, mouth rinses, gels, and varnishes. In addition, materials have been introduced delivering fluoride during treatment such as fluoride-releasing composite bonding materials (resin modified), glass ionomer cements (GIC), compomers, slow-release fluoride devices, and fluoride-releasing elastomeric ligatures [8].

Unfortunately, preventive and chemoprophylactic products, such as high-fluoride toothpaste or gel, fluoride varnish, and chlorhexidine rinse, gel, or varnish, are rarely prescribed by orthodontists. It was reported that 95% of orthodontists provided oral hygiene instructions, while only 52% prescribed fluoride mouth rinse [9].

The caries risk of prolonged duration of orthodontic treatment can be minimized by a continuous fluoride release from the bonding system around the bracket base. The introduction of fluoride-releasing adhesive systems, sealants, and glass ionomer cements for bracket bonding offered a means of fluoride delivery adjacent to bracket–enamel interface independent of patient cooperation [10]. The critical factors for success of these materials are adequate bond strength for orthodontic appliances and sustained fluoride release. Fluoride materials that have previously been investigated as bonding agents include fluoride-releasing composite resin and glass ionomer cements [11]. Glass ionomers have been shown in vitro to be effective at protecting the enamel from decalcification beneath and also 1 mm around an orthodontic attachment [12]. However, highly significant weaker bond strength of glass ionomer cement was found compared with conventional bonding adhesives. Because of this weaker bond strength, the clinical acceptability of these adhesives as orthodontic bonding material has been questioned [13,14]. The potential advantages of a product delivering fluoride beneath and closely around the orthodontic bonded attachments, independent of patient compliance, has led to the development of fluoride releasing adhesives [15].

The new Transbond™ Plus Color Change Adhesive contains a fluoroaluminosilicate glass as the fluoride source. The hydrophilic nature of the adhesive allows fluoride diffusion through the cured cross-linked matrix in an aqueous medium [16]. Its pink color provides a visual aid for bracket positioning and excess removal of the adhesive. Upon light curing, the color immediately fades.

The purpose of the present study was to evaluate the in vivo effects of the fluoride releasing Transbond™ Plus Color Change Adhesive in reducing enamel demineralization around orthodontic brackets and compare it with non-fluoride releasing Transbond™ XT. Enamel surface topography around orthodontic brackets was assessed using scanning electron microscope and the mineral contents of the enamel surface were evaluated using energy dispersive x-ray microanalysis.

2. Materials and methods

This study was carried on twenty patients from orthodontic clinic at Faculty of Dentistry, Tanta University, scheduled to have maxillary premolars extracted as a part of orthodontic treatment. The age was 13–16 years. The criteria for teeth selection in this study included intact buccal enamel with no caries or hypoplastic areas, no cracks or gross irregularities, no restorations and not subjected to any chemical agent affecting the enamel such as alcohol, hydrogen peroxide, formaldehyde and so forth.

All patients and their guardians involved in this study signed a written consent. The patients in this study were randomly divided into 2 groups of 10 each according to the type of adhesive used: Group I; Twenty brackets were bonded with the fluoride releasing Transbond™ Plus Color Change Adhesive* while Group II; Twenty brackets were bonded with the conventional non-fluoride releasing Transbond™ XT† to upper first premolars.

2.1. Bonding procedures

The enamel surface of each tooth was polished with fluoride-free pumice and rubber cup for 10 s, sprayed with water and dried with compressed oil-free stream. A piece of tape with a cut-out the size of a bracket base was applied to each tooth during bonding. This was done to restrict spread of etchant on the adjacent enamel, which could prematurely initiate demineralization. Tape was

† 3M Unitek Orthodontic Products, Monrovia, California, USA.
used on all experimental teeth to standardize the protocol.

Enamel surface was treated with 37% phosphoric acid for 30 s then the piece of tape was carefully removed. The tooth was rinsed with water for another 30 s and dried. A thin uniform coating of sealant resin was applied on the etched area with a disposable brush and gently air-dried. The paste was gently pressed onto the bracket base with a spatula. The bracket was then immediately placed onto the tooth surface. Premolar brackets were randomly bonded to the treated enamel surfaces with either Transbond™ Plus Color Change Adhesive or Transbond™ XT following manufacturer’s instructions. The brackets were positioned on the facial surface at the height of contour mesiodistally, in the middle one third occlusogingivally, and parallel to the long axis of the tooth. The brackets were pressed on the enamel surface until fully seated. Excess adhesive around the bracket was carefully removed with a clinical probe before curing. The bonding agent was cured with a Chromalux, visible light curing unit for 40 s. T-loops were formed with 0.014 inch stainless steel wire and engaged on experimental and control teeth with elastomeric rings to increase plaque accumulation Fig. 1.

During the experimental period, the patients received detailed verbal and written oral hygiene instruction and were informed to brush three times daily with a dentifrice provided to them, containing 1450 ppm fluoride. The patients or their parents were asked to complete a log of their daily tooth-brushing schedules. The patients were instructed not to use any mouth wash. The patients were recalled every 2 weeks to reinforce oral hygiene instruction. After 60 days, the brackets were debonded and teeth were carefully extracted. The teeth were scrapped and cleaned of remnants of periodontal ligaments, disinfected and stored in distilled water before use. The extracted teeth of each group were divided into two equal subgroups of ten each (diagram).

2.1.1. Teeth preparation for scanning electron microscope examination

The crowns of each subgroup (A and A*) were first sectioned from the roots with a low speed double sided diamond disk and continuous water spray irrigation. Then each crown was cut on a mesiodistal line from occlusal to cervical and the buccal surfaces were stored in distilled water. All specimens were mounted on stubs and prepared for scanning electron microscope by sputtering with gold. They were examined in scanning electron microscope (JEOL JSM-5200 Japan), operated at 15 KV. The buccal surfaces of the teeth were examined carefully occlusal, proximal and gingival to the orthodontic bonding area to obtain the representative photomicrographs.

2.1.2. Teeth preparation for scanning electron microscope and energy dispersive X ray microanalysis

The crowns of each subgroup (B and B*) were first sectioned from the roots with a low speed double sided diamond disk and continuous water spray irrigation. Then each crown was cut on a buccolingual line from lingual to half way the buccal surface then the two parts were separated using osteotome and hammer to have clean cuts and the cut surfaces were stored in distilled water. All specimens were mounted on stubs without coating and examined in scanning electron microscope (JEOL JSM-6510LA Japan), then the elemental analysis was performed using the energy dispersive X ray microanalysis unit attached to the same scanning electron microscope. The cut surfaces of the teeth were examined carefully occlusal and gingival to the orthodontic bonding area to obtain the representative photomicrographs.
2.1.3. Statistical analysis

Descriptive statistics including the mean, standard deviation, and maximum and minimum values were calculated for each element in both groups. Comparisons of the mineral contents within the same group were performed with Paired $t$-test whereas comparisons of the mineral contents between the two groups were performed with student $t$-test. Significant differences for all statistical tests were predetermined at $P \leq 0.05$. All statistical evaluations were made with a software program (SPSS version 15).

3. Results

3.1. SEM examination

3.1.1. Group I (the fluoride releasing Transbond™ Plus Color Change Adhesive)

SEM examination of the enamel surface occlusal to the orthodontic bonding area (OBA) revealed almost normal topographic features of enamel. In some cases, there were globules of calcium fluoride like material irregularly distributed over the enamel surface. This globular calcification were arranged around enamel rod peripheries whereas some rods were occluded Fig. 2.

The enamel surface proximal to the OBA revealed almost normal topographic features of enamel. Signs of remineralization of enamel were clearly observed in close proximity to as well as away from composite remnants Fig. 3.

In other specimens, globules of calcium fluoride like material were detected resulting in areas of enamel remineralization with occlusion of enamel rods and repair of fractured enamel surface. Despite the presence of globules of calcium fluoride like material over the enamel surface gingival to the OBA, there were some focal holes spread throughout the relatively smooth enamel surface Fig. 4

A buccolingual cross section of the buccal surface revealed the presence of globular calcification of calcium fluoride like particles all the way around the rod periphery occlusally and gingivally. Fig. 5 resulting in complete and/or partial remineralization of eroded enamel prisms and fractured enamel.

3.1.2. Group II (The conventional non-fluoride releasing Transbond™ XT)

SEM observation of the enamel surface occlusal to the OBA revealed roughened enamel surface with multiple areas of enamel erosion Fig. 6. Various patterns of enamel decalcification were observed proximal to the OBA in the form of open focal holes and demineralization of enamel rod core as well as cracks and accentuated perikymata which resulted in the formation of gap in the enamel surface Fig. 7.

The gingival region next to the OBA exhibited highly roughened enamel surface and erosion of enamel rod cores Fig. 8. A buccolingual cross section of the buccal surface occlusal to the OBA revealed erosion of enamel rods in close proximity to enamel surface which resulted in formation of gaps between rods and enamel surface Fig. 9.

On other hand, extensive erosions of enamel rods were detected gingival to the OBA which resulted in gaps between enamel rods as well as gap between rods and enamel surface Fig. 10.

3.1.3. EDX evaluation

The descriptive statistics for the percentage of calcium mass for each group are presented in Table 1 including the mean, standard deviation, maximum and minimum values.

The mean Calcium mass % occlusal and gingival to OBA for each group is graphically presented in Fig. 11. Calcium mass % occlusal to OBA in group I yielded the highest mean whereas Calcium mass % occlusal to OBA in group II.
gingival to OBA in group II yielded the lowest mean. Table 1, Fig. 11.

Calcium mass % values occlusal to the OBA yielded high significant increase relative to its gingival counterpart in the Transbond Plus group (P = 0.001). Also, it was significantly increased in the Transbond XT group (P = 0.027) compared with its gingival counterpart. Table 2. The Transbond Plus group yielded significant increase in Calcium mass % values both occlusal and gingival to the OBA compared with the Transbond XT group (P = 0.019, P = 0.006 respectively). Table 2.

The descriptive statistics for the percentage of Fluoride mass for each group are presented in Table 3 including the mean, standard deviation, maximum and minimum values.

The mean Fluoride mass % occlusal and gingival to the OBA for each group is graphically presented in Fig. 12. Fluoride mass % occlusal to OBA in group I produced the highest mean whereas Fluoride mass % gingival to OBA in group II produced the lowest mean. Table 3, Fig. 12.

The statistical analysis of Fluoride mass % values between occlusal and gingival to OBA within group I (The Transbond Plus group) was statistically nonsignificant (P = 0.284) whereas in group II (Transbond XT group), it revealed significant difference (P = 0.039). It is clear that the Transbond Plus group yielded highly significant increase in Fluoride mass % values both occlusal and gingival to the OBA in comparison with the Transbond XT group (P = 0.001, P = 0.000 respectively) Table 4.

The descriptive statistics for the percentage of phosphorous mass for each group are presented in Table 5 including the mean, standard deviation, maximum and minimum values.

The mean phosphorous mass % occlusal and gingival to the OBA for each group is graphically presented in Fig. 13. Phosphorous mass % occlusal to OBA in group I showed the lowest mean whereas phosphorous mass % gingival to OBA in group II showed the highest mean. Table 5, Fig. 13.

As illustrated in Table 6 there was variation in Phosphorous mass % values between occlusal and gingival to OBA within the Transbond Plus group, but this difference didn’t reach the statistical significance (P = 0.283) whereas in Transbond XT group, there was statistically significant difference (P = 0.021). In Transbond Plus group, highly significant reduction of Phosphorous mass % occurred whether occlusal or gingival to the OBA relative to its counterpart in Transbond XT group (P = 0.001, P = 0.000 respectively).

4. Discussion

There is no doubt that the prevention of demineralization is one of the responsibilities of the orthodontist who is concerned with high quality treatment.
Thus, using fluoride containing sealants and adhesives to bond brackets has been attempted [10]. The new Transbond™ Plus Color Change Adhesive contains a fluoroaluminosilicate glass as the fluoride source. The hydrophilic nature of the adhesive allows fluoride diffusion through the cured cross-linked matrix in an aqueous medium [16].

Although several studies have been conducted on the cariostatic effect of fluoride-releasing materials by using a split-mouth design, in the current study the subjects were randomly divided into 2 groups, and each received only one tested material, because the prior clinical and radiographic examinations showed that the patients were equivalent with regard to caries risk or activity. This experimental design was chosen rather than the split-mouth technique, to avoid the carry-across effect due to fluoride release by the fluoride releasing adhesive on enamel around the brackets bonded with non-fluoride releasing adhesive. This may confound the results and limit the robustness of any findings.

For ethical reasons and because of the long duration of the in-vivo experiment (2 months), it was inappropriate to ask the patients not to brush their teeth. So, they were instructed to brush twice daily with a fluoride containing toothpaste. Nevertheless, to minimize the bias of additional external fluoride supplements, they were strictly asked to refrain from any fluoride mouth rinses and not to have fluoride treatment from their dentists during the 2 months of the study.

In the present study, only upper premolars were subjected to the experiment. This might lessen the remineralizing capacity of saliva. Ogaard et al. (1988) [3] suggested a relationship between resistance to white spot formation and the rate of salivary flow. The lower dentition might be more susceptible to influence of the saliva because of the anatomic situation of the salivary glands and gravity that may result in a higher degree of saliva contact in the lower jaw.

Measurable demineralization can be observed around orthodontic appliances 1 month after bonding [3]. A two months experimental period was used in the present study. The ligated T loops were left on an additional 30 days in an attempt to obtain a longer period of caries attack.

SEM of the enamel surface of the fluoride-releasing material (group I) occlusal and proximal to the OBA revealed almost normal topographic features of enamel. It also revealed deposition of globules of calcium fluoride like material over the enamel surface resulting in areas of enamel remineralization with occlusion of enamel rods and repair of fractured enamel surface. These globular calcification were arranged around enamel rod peripheries as well as all way of inter-rod region surrounding the enamel rods. In the control samples, no such globules were observed. Such observations are similar to those reported by Nelson et al., (1983) [17] Ogaard, (1990) [18] and Bykyilmaz et al. (1994) [19] after topical fluoride applications.
Because of their resemblance in appearance to calcium fluoride (spherical globules), one could speculate that these particle depositions most likely represent calcium fluoride, a salt with clearly cariostatic properties [20]. Calcium fluoride that has formed on the enamel surface may act as a potential reservoir, slowly releasing fluoride ions available for use in remineralization or redeposition into areas of demineralization, or acting as a diffusion barrier during acid attacks [18]. Dissociation of fluoride ions from calcium fluoride crystals and diffusion into the pores in the enamel may have occurred, either during the initial intense release or later during the slow but regular exposure to fluoride, followed by incorporation into the enamel apatite crystals as fluoroapatite during demineralization and remineralization procedures, finally forming larger, more acid resistant crystals [20].

During remineralization minerals are initially deposited in or near the surface layer and then are gradually transferred inward in the deeper part of the lesion body [21]. This corroborates the findings in the present study where globules of calcium fluoride like material were deposited in the subsurface and deeper part of the enamel all the way along enamel rod peripheries. It indicates sustained release of low fluoride level in Transbond™ Plus Color Change Adhesive. This finding confirms investigations which showed that continuous application of a low dose of fluoride had a greater cariostatic effect than did individual applications of high doses [22–24].

However, scanning electron micrograph of enamel surface gingival to bracket of group I revealed some focal holes spread throughout the enamel surface. This can be explained by the fact that fluoride cannot prevent the formation of such enamel lesions, but it did reduce their progression. This agrees with the findings of Farhadian et al. (2008) [25] who found some demineralization in all experimental teeth. However, these findings disagree with a lot of authors [4,26–28] who found that fluoride containing adhesive showed no reduction in decalcification when compared to conventional orthodontic bonding resin. The difference in demineralization protection may be attributed to the amount of fluoride released by materials as stated by Basdra et al. (1996) [20]. Chadwick and Gordon, (1995) [29] reported that 70 percent of fluoride is released in the first month. Another possible
explanation for this difference may be the bacterial challenge which can overcome the protection afforded by fluoride and remineralization [30].

In spite of brushing daily with fluoride containing toothpaste, SEM observation of group II (Transbond XT group) revealed various patterns of enamel decalcification in the form of open focal holes and demineralization of enamel rod core as well as cracks and accentuated perikymata which resulted in the formation of gap in the enamel surface. This is parallel to a study by O’Reilly and Featherstone (1987) [2] showing that regular use of fluoridated tooth pastes during orthodontic treatment was not sufficient to inhibit caries development.

Also, researchers reported that the numerous focal holes observed are natural defects always present in sound enamel [3]. The focal holes are not empty spaces but most likely are filled with organic material. It has been suggested that these spots appear to be the initial sites of acid penetration during lesion formation as acids diffuse easily into the defects and then into the spaces between the crystallites [31–34]. This supports the current findings.

Previous studies have reported that acid etching prior to enamel bonding is a possible causative factor in the decalcification associated with orthodontic treatment [2]. Etching demineralizes the enamel surface at depths ranging from 5 μm to 25 μm [35]. Importantly, the acid-etched surface allows the less mineralized underlying enamel to be exposed to a potentially acidic microenvironment [36]. Etched enamel exposed to cariogenic solutions has been shown to be more severely affected than is unetched enamel [37]. Enamel decalcification may also be caused by the adhesive resin used to bond brackets to enamel. The polymeric structure of resins hosts a variety of microorganisms. Increases in bacterial accumulation have been reported at composite sites [38]. Bacteria not only adhere to, but also consume and colonize within, the composite resin Ref. [39]. An increase in bacterial accumulation following orthodontic appliance placement has been observed [40]. The firmly ligated T loops were used in the current study providing more areas for plaque and bacteria retention and make plaque removal more difficult.

EDX is defined as a quantitative, semi quantitative or qualitative method for identification of chemical elements in a wide variety of samples. The technique sensitivity of this method depends on the atomic number of the element to be identified, the atomic number of all elements present in the sample and the technique used during sample preparation for

![Fig. 10. SEM of a buccolingual cross section gingival to OBA of group II showing enamel rods appear with severe erosions making gaps (arrow) between enamel rods as well as gap between rods and enamel surface (arrow head).](image)

![Fig. 11. Mean Calcium mass % occlusal and gingival to OBA in the two studied groups.](image)

<table>
<thead>
<tr>
<th>Calcium mass %</th>
<th>Occlusal</th>
<th>Gingival</th>
<th>Paired t-test</th>
</tr>
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<tbody>
<tr>
<td>Group I</td>
<td>68.404</td>
<td>64.086</td>
<td>4.542 0.001**</td>
</tr>
<tr>
<td>(Transbond Plus)</td>
<td>64.500</td>
<td>58.644</td>
<td>2.633 0.027*</td>
</tr>
<tr>
<td>Group II</td>
<td>64.084</td>
<td>58.644</td>
<td>4.542 0.001**</td>
</tr>
<tr>
<td>(Transbond XT)</td>
<td>64.500</td>
<td>58.644</td>
<td>2.633 0.027*</td>
</tr>
</tbody>
</table>

Table 2
Comparative statistics of calcium mass % within each group and between the two studied groups.

Table 1
Descriptive statistics for the percentage of calcium mass.

<table>
<thead>
<tr>
<th>Calcium</th>
<th>Mean ± S.D.</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusal</td>
<td>68.4</td>
<td>2.68773</td>
<td>71.63</td>
</tr>
<tr>
<td>Gingival</td>
<td>64.5</td>
<td>2.3610</td>
<td>69.95</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusal</td>
<td>64.086</td>
<td>4.57067</td>
<td>71.69</td>
</tr>
<tr>
<td>Gingival</td>
<td>58.644</td>
<td>5.40446</td>
<td>66.23</td>
</tr>
</tbody>
</table>
The present study analyzed only calcium, phosphorus, and fluoride, whose atomic numbers are 20, 15, and 9, respectively. The calcium, phosphorous, and fluoride present show considerable evidence as being caries preventive agents [42]. If present at the time of acid attack, fluoride in particular will diffuse with the acid and inhibit enamel dissolution [43]. If present during remineralization, it enhances crystal growth and encourages mineral precipitation. It may in fact render the enamel more resistant to subsequent attacks [44].

The results of the present study showed a significant difference in calcium, phosphorus, and fluoride contents in the Transbond Plus group compared to the Transbond XT group. There were higher levels of calcium and fluoride in the Transbond Plus group. It is attributed to calcium fluoride deposition on the teeth bonded with fluoride releasing composite on enamel surface adjacent to the OBA.

EDX analysis revealed higher phosphorus content in the Transbond XT group, which could be explained by the greater presence of calcium and fluoride in the Transbond Plus group. It is attributed to calcium fluoride deposition on the teeth bonded with fluoride releasing composite on enamel surface adjacent to the OBA.

The results of the present study showed decreased mineral content (calcium and fluoride) in the cervical region than in the occlusal area. This result is matched with SEM observation. This might be due to greater dental plaque accumulation and the patient’s difficulty in cleaning this area [47]. This finding is in accordance with that of Gorelick et al. (1982) [1] and Øgaard (1989) [48] who found that enamel demineralization around the brackets is commonly seen on the buccal surfaces of teeth, especially in the gingival region.

The results of the present study indicate that one can in fact decrease the formation of very early demineralization of enamel surrounding the orthodontic appliances with the use of fluoride releasing adhesive.
independent of patient cooperation. Sustained release of a low level of fluoride leads to the formation of a calcium-fluoride coat at the enamel surface. This reservoir of fluoride at the enamel surface has a high substantivity that can provide fluoride for remineralization and calcium for neutralization of the acid attack.

5. Conclusion

On the basis of the current results, it’s suggested to use the fluoride releasing Transbond™ Plus Color Change Adhesive with orthodontic brackets especially in patients exhibiting poor oral hygiene or have dietary risks.

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References


