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Effects of adhesion promoters on the shear bond strengths of orthodontic brackets to fluorosed enamel

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SUMMARY The aims of this *in vitro* study were to evaluate the effect of enamel fluorosis on the shear bond strength (SBS) of orthodontic brackets and to determine whether adhesion promoter, Enhance LC, increases the bond strength of brackets to fluorosed enamel.

Forty-five (30 fluorosed and 15 non-fluorosed) non-carious fresh human premolar teeth, extracted for orthodontic reasons and without any caries or visible defects, were used in this study. The fluorosed teeth were selected according to the modified Thylstrup and Fejerskov index, which is based on the clinical changes in fluorosed teeth. In groups 1 (fluorosed teeth) and 3 (control), the brackets were bonded with Light Bond composite resin and cured with a halogen light. In group 2, Enhance LC was applied to fluorosed enamel before bonding. After bonding, the SBS of the brackets was tested with a universal testing machine. One-way analysis of variance and Tukey multiple comparison tests were used to compare the SBS of the groups. Any adhesive remaining after debonding was assessed and scored according to the modified adhesive remnant index.

The results showed that while fluorosis significantly reduced the bond strengths of the orthodontic brackets (mean 13.94 ± 3.24 MPa; $P < 0.01$), Enhance LC significantly increased bond strength on fluorosed enamel (mean 18.22 ± 5.97 Mpa; $P < 0.05$). Groups 1 and 3 had greater bond failures at the composite–bracket interface, whereas group 2 showed bond failure primarily at the enamel–composite interface.

Introduction

Enamel fluorosis is the hypomineralization of the enamel caused by continuous ingestion of excessive fluoride, greater than 1–2 ppm, during enamel formation (Fejerskov *et al.*, 1994). Fluorosed enamel is characterized by an outer hypermineralized, acid-resistant layer, and retention of more porous enamel in the areas of the subsurface hypomineralization (Haywood and Berry, 2001). Orthodontists working in endemic fluorosis regions (e.g. Colorado, USA; Sri Lanka; Isparta, Turkey; Hail Region, Saudi Arabia may face difficulties in bonding brackets to fluorosed teeth. In a clinical situation, debonding of brackets from fluorosed enamel can occur soon after the orthodontic bracket is positioned as a result of stress (Miller, 1995; Weerasinghe *et al.*, 2005). Repeated bonding is time consuming and has a negative effect on successful orthodontic treatment.

Several authors have investigated bond strength between composite materials and fluorosed enamel (Opinya and Pameijer, 1986; Ng'ang'a *et al.*, 1992; Awliya and Akpata, 1999; Ateyah and Akpata, 2000; Weerasinghe *et al.*, 2005; Adanir *et al.*, 2007). Ng'ang'a *et al.* (1992) reported no significant differences in the bond strengths between fluorosed and normal enamel. On the other hand, Weerasinghe *et al.* (2005) found that the severity of fluorosis adversely affected the micro shear bond strength (SBS) of a self-etching bonding system to fluorosed enamel. These conflicting results can be explained by the differences in the materials used and the severity of fluorosis.

Some investigators have recommended extended enamel conditioning with phosphoric acid when bonding composite resin to fluorosed enamel to remove the acid resistant hypermineralized surface layer and increase SBS (Opinya and Pameijer, 1986; Ateyah and Akpata, 2000). In addition, adhesion promoters to enhance the bond strength of the brackets and to save chairside time have been introduced in orthodontics in the last decades. One of these materials is Enhance LC (Reliance, Itasca, Illinois, USA). The manufacturers claim that it significantly increases adhesion of resins to fluorosed, hypocalcified, or primary enamel. It is composed of hydroxyethyl methacrylate (HEMA), tetrahydrofurfuryl cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional groups, one hydrophobic and the other hydrophilic (Nakabayashi *et al.*, 1982). Hydrophilic monomers in these adhesive systems help resin infiltrate enamel etched at the level of the prisms. This characteristic should reduce interfacial porosity and therefore increase adhesion, achieving greater bond strength through polymerization (Hotta *et al.*, 1992).

The efficiency of these adhesion promoters on bond strengths of brackets to enamel has been tested in several *in vivo* and *in vitro* studies (Newman *et al.*, 1995; Chung *et al.*, 2000; Vicente *et al.*, 2004, 2006; Noble *et al.*, 2008). However, no study has evaluated the effect of adhesion promoters to the SBS of orthodontic brackets to fluorosed teeth.

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Therefore, the aims of this *in vitro* study were to evaluate the effect of enamel fluorosis on the SBS of orthodontic brackets and to determine whether adhesion promoters increase bond strengths of brackets to fluorosed enamel.

The null hypotheses tested were that enamel fluorosis did not decrease the bond strength of orthodontic brackets and the adhesion promoters did not increase the bond strength of orthodontic brackets to fluorosed enamel.

Materials and methods

Forty-five (30 fluorosed and 15 non-fluorosed) non-carious human permanent premolar teeth freshly extracted for orthodontic reasons and without any caries or visible defects were used in this study. The fluorosed teeth were selected according to the modified Thylstrup and Fejerskov index (TFI), which is based on the clinical changes in fluorosed teeth (Fejerskov *et al.*, 1994). The specific features of teeth with a TFI score of 4 are a marked opacity and a chalky white appearance on the entire surface. Each tooth was individually embedded in autopolymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany). The specimens were kept in distilled water except during the bonding and testing procedures. The 30 fluorosed teeth were divided into two equal groups. Fifteen non-fluorosed teeth (TFI score of 0) served as the control group.

Group 1—fluorosed teeth (TFI score 4)

Before bonding, the facial surfaces of the teeth were cleaned with a mixture of water and pumice. The teeth were rinsed thoroughly with water and dried with oil and moisture-free compressed air. Each tooth was etched with 37 per cent phosphoric acid gel (Gel Etch®, 3M Unitek, Monrovia, California, USA) for 30 seconds, rinsed with a water/spray combination for 30 seconds, and dried until a characteristic frosty white etched area was observed. Ormco Mini 2000 (Ormco Corp., Glendora, California, USA) premolar metal brackets with a 9.63 mm^2 surface area were used. Light Bond (Reliance) was used as the orthodontic adhesive. With a microbrush, a thin uniform layer of sealant was applied on the etched enamel and cured for 20 seconds. A thin coat of sealant was also painted on the metal bracket base and cured for 10 seconds before applying the paste. Using a syringe tip, the paste was applied to the bracket base. The bracket was then positioned on the tooth and an explorer was used to seat the brackets with a constant force. Excess adhesive was removed with a sharp scaler and cured with a Heliolux DLX (Vivadent ETS, Schaan, Liechtenstein) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surface of the brackets).

Group 2—fluorosed teeth (TFI score 4)

A thin layer of Enhance LC was applied on the etched fluorosed enamel and dried with compressed air according to the manufacturer's recommendation. A thin layer of Light Bond sealant was then applied directly on the Enhance LC coated layer and light cured for 10 seconds. The bracket was bonded with Light Bond as previously described.

Group 3—control (TFI score 0)

The brackets were bonded to non-fluorosed teeth with Light Bond the same as in group 1.

All specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5 and 55°C, using a dwell time of 30 seconds. Each specimen was loaded into universal testing machine (Lloyd, Fareham, Hants, UK) using Nexjen software (Charlotte, North Carolina, USA) for testing, with the long axis of the specimen being perpendicular to the direction of the applied force. A standard knife-edge was positioned to make contact with the bonded specimen (Figure 1). Bond strength was determined in shear mode at a crosshead speed of 0.5 mm/minute until fracture occurred. Failure load values (N) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base (9.63 mm^2).

After debonding, all teeth and brackets in the test groups were analyzed using a light stereomicroscope (Olympus SZ 6045 TR Zoomstereomicroscope, Olympus Optical Co.,

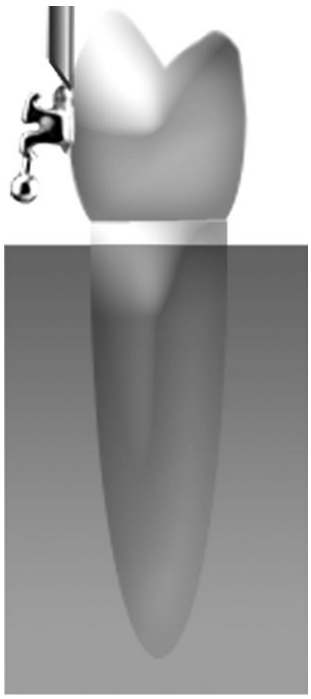


Figure 1 Schematic representation of the specimen in the test machine. The standard knife-edge was positioned to make contact with the bonded specimen and directed parallel to the long axis of the crown of the tooth.

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Osaka, Japan) at ×10 magnification to determine the bracket–failure interface. Any adhesive remaining after debonding was assessed and scored according to the modified adhesive remnant index (ARI; Olsen *et al.*, 1997). The scoring criteria of the index are as follows:

1 = all of the composite, with an impression of the bracket base remained on the tooth;
2 = more than 90 per cent of the composite remained on the tooth;
3 = more than 10 per cent but less than 90 per cent of the composite remained on the tooth;
4 = less than 10 per cent of composite remained on the tooth;
5 = no composite remained on the tooth.

Statistical analysis

Descriptive statistics, including the mean, standard deviation, standard error, minimum, and maximum values, were calculated for each of the test groups. One-way analysis of variance (ANOVA) and Tukey multiple comparison tests were used to compare the SBS of the groups. The chi-square test was used to determine significant differences in the ARI scores among the groups. Significance for all statistical tests was predetermined at $P < 0.05$. All statistics were performed using the Statistical Package for Social Sciences version 11.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Descriptive statistics for the SBS (MPa) of the groups are presented as box plots in Figure 2. All groups displayed clinically acceptable mean bond strengths (over 8 MPa). ANOVA indicated a significant difference between groups ($P < 0.01$; Table 1). SBS in group 1 was significantly lower than in groups 2 and 3 ($P < 0.05$ and $P < 0.01$, respectively). No significant difference was found between groups 2 and 3 ($P > 0.05$).

Frequency distribution of the ARI scores and chi-square comparison of the groups are presented in Table 2. There was a significant difference between groups ($P < 0.01$). Groups 1 and 3 had greater bond failures at the composite–bracket interface, whereas group 2 showed bond failure primarily at the enamel–composite interface.

Discussion

Successful orthodontic treatment depends on an adequate bond strength of brackets to enamel. The minimum bond strength required to withstand normal orthodontic forces is believed to be between 6 and 8 MPa (Reynolds, 1975). In the present study, SBS ranged from 13.94 to 19.29 MPa. The lowest values (mean = 13.94 MPa) were obtained

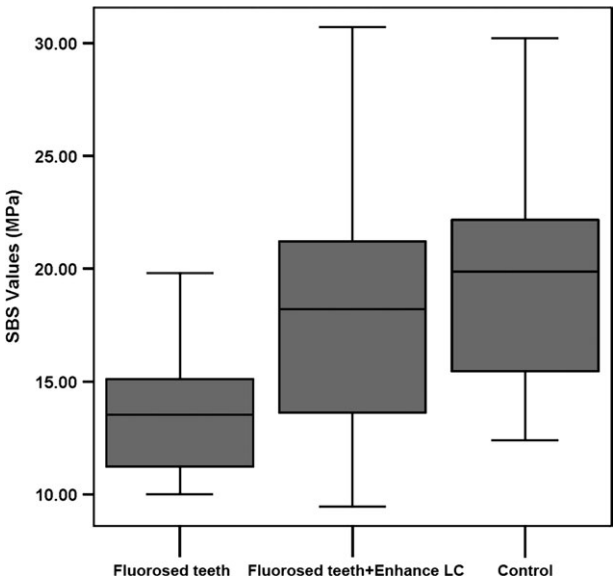


Figure 2 Box plot showing the shear bond strengths (MPa) of the groups. The horizontal line in middle of each box plot shows the median value; horizontal lines in the boxes show the 25 and 75 per cent quartiles and those outside the box the 5 and 95 per cent quartiles.

when brackets were bonded to fluorosed enamel with Light Bond. The findings demonstrate that fluorosis significantly reduced the SBS of brackets to enamel. This decrease may be due to the acid resistant outer layer of the fluorosed enamel. Therefore, the first null hypothesis was rejected.

These findings are consistent with those of Weerasinghe *et al.* (2005) who reported that the severity of fluorosis affected the micro SBS of a self-etching bonding system to fluorosed enamel. In contrast to the present study, Ng'ang'a *et al.* (1992) found no statistically significant difference between the mean strength values for orthodontic brackets bonded to fluorosed and non-fluorosed teeth. They bonded brackets with a composite resin after over etching the enamel surface with 40 per cent phosphoric acid for 60 seconds. The result of their study revealed that fluorosis decreased the bond strength compared with non-fluorosed teeth. However, the difference between the means for bond strength was not statistically significant.

Opinya and Pameijer (1986) and Ateyah and Akpata (2000) recommended extended enamel conditioning with phosphoric acid, removing the acid-resistant hypermineralized surface layer (outer 200 μm) or adhesion promoter use when bonding composite resin to fluorosed enamel to increase bond strength. One commercially available adhesion promoter specifically for use in orthodontics is Enhance LC. Enhance LC is composed of HEMA, tetrahydrofurfuryl cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional groups, one hydrophobic and the other hydrophilic (Nakabayashi *et al.*, 1982). Incorporation of hydrophilic

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Table 1 Results of analysis of variance comparing the shear bond strengths of the groups.

Group 1 (fluorosed teeth)		Group 2 (fluorosed teeth + Enhance LC)		Group 3 (control)		Significance	*Post hoc* tests		
Mean	SD	Mean	SD	Mean	SD		1–2	1–3	2–3
13.94	3.24	18.22	5.97	19.29	4.71	0.009**	*	**	NS

*$P < 0.05$; **$P < 0.01$. SD, standard deviation; NS, non-significant.

Table 2 Frequency distribution of the Adhesive Remnant Index (ARI) scores and the chi-square comparison of the groups.

Test groups	ARI scores						
	1	2	3	4	5	*n*	Test
Group 1 (fluorosed teeth)	2	5	6	0	2	15	0.006**
Group 2 (fluorosed teeth + Enhance LC)	1	0	4	9	1	15	
Group 3 (control)	3	5	4	1	2	15	

**$P < 0.01$.

monomers in adhesive systems helps resin infiltrate enamel etched at the level of the prisms. This characteristic should reduce interfacial porosity and therefore increase adhesion, achieving a greater bond strength through polymerization (Hotta *et al.*, 1992). On the basis of these concepts, such composite resins are being introduced into various orthodontic adhesives in order to increase bond strength (Eliades and Eliades, 2001).

Contradictory results exist in the literature concerning the effects of adhesion promoter agents on the bond strength of orthodontic brackets to non-fluorosed enamel. Previous studies have revealed that the application of Enhance LC on etched enamel surface or on the bracket base of a debonded bracket failed to increase rebond strength (Egan *et al.*, 1996; Chung *et al.*, 2000). Chung *et al.* (2000) evaluated the effects of two adhesion promoters, Enhance LC and All-Bond 2, on the SBS of new and rebonded (previously debonded) brackets. They found that Enhance LC failed to increase the bond strength of sandblasted rebonded brackets. However, when new brackets were used, Enhance LC improved bond strength but there was no significant difference compared with controls. Vicente *et al.* (2006) also found a statistically non-significant increase in bond strengths when Enhance LC and Light Bond were used together.

In the present study, the brackets bonded with Enhance LC exhibited a significant increase in bond strength. This result is somewhat surprising since most of the previous studies failed to find a statistically significant increase. This can be explained by the differences in the materials used. This appears to be the first study where the effects of the Enhance LC have been tested on fluorosed teeth. It may be that the promoting effect of the material could be realized in hypercalcified fluorosed enamel.

On the basis of these results, the second null hypothesis was also rejected. Adhesion promoter, Enhance LC, significantly increased the SBS of brackets to fluorosed enamel.

The amount of adhesive remaining on the tooth was recorded using the ARI (Olsen *et al.*, 1997). ARI scores are used to define the site of bond failure between the enamel, the adhesive, and the bracket base. Bond failures within the adhesive or at the bracket–adhesive interface is preferred because it decreases the shear force stress at the enamel surface and increases the probability of maintaining an undamaged enamel surface (Olsen *et al.*, 1997). In the present study, although Enhance LC significantly increased the bond strength of brackets to fluorosed enamel, it also resulted in an increased ARI score. Thus, the bonds created by adhesion promoter failed in a more unfavourable location than those created by conventional bonding agents.

Conclusions

1. Enamel fluorosis significantly decreased the bond strength of orthodontic brackets.
2. Enhance LC significantly increased the bond strengths of brackets to fluorosed enamel.
3. There is a significant change in bond failure location to a more unfavourable site (enamel–adhesive interface) with the use of Enhance LC.

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References

Adanir N, Turkkahraman H, Gunor A Y 2007 Effects of fluorosis and bleaching on shear bond strength of orthodontic brackets. Eur J Dent 1: 230–235

Ateyah N, Akpata E S 2000 Factors affecting shear bond strength of composite resin to fluorosed human enamel. Operative Dentistry 25: 216–222

Awliya W Y, Akpata E S 1999 Effect of fluorosis on shear bond strength of glass ionomer-based restorative materials to dentin. Journal of Prosthetic Dentistry 81: 290–294

Chung C H, Fadem B W, Levitt H L, Mante F K 2000 Effects of two adhesion boosters on the shear bond strength of new and rebonded orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 118: 295–299

Egan F R, Alexander S A, Cartwright G E 1996 Bond strength of rebonded orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 109: 64–70

Eliades T, Eliades G 2001 Orthodontic adhesives resins. In: Brantley W A, Eliades T (eds). Orthodontic materials. Scientific and clinical aspects, Thieme, New York, pp. 201–220.

Fejerskov O, Larsen M J, Richards A, Baelum V 1994 Dental tissue effects of fluoride. Advances in Dental Research 8: 15–31

Haywood V B, Berry T G 2001 Natural tooth bleaching. In: Summitt J B, Rabbins J W, Schwartz R S (eds). Fundamentals of operative dentistry: a contemporary approach, Quintessence Publishing Co. Inc., Chicago, p. 402

Hotta K, Mogi M, Miura F, Nakabayashi N 1992 Effect of 4-MET on bond strength and penetration of monomers into enamel. Dental Materials 8: 173–175

Miller R A 1995 Bonding fluorosed teeth: new materials for old problems. Journal of Clinical Orthodontics 29: 424–427

Nakabayashi N, Kojima K, Masuhara E 1982 The promotion of adhesion by the infiltration of monomers into tooth substrates. Journal of Biomedical Materials Research 16: 265–273

Newman G V, Newman R A, Sun B I, Ha J L, Ozsoylu S A 1995 Adhesion promoters, their effect on the bond strength of metal brackets. American Journal of Orthodontics and Dentofacial Orthopedics 108: 237–241

Ng'ang'a P M, Øgaard B, Cruz R, Chinidia M L, Aastrum E 1992 Tensile bond strength of orthodontic brackets bonded directly to fluorotic and nonfluorotic teeth: an *in vitro* comparative study. American Journal of Orthodontics and Dentofacial Orthopedics 102: 244–250

Noble J, Karaiskos N E, Wiltshire W A 2008 *In vivo* bonding of orthodontic brackets to fluorosed enamel using an adhesion promoter. Angle Orthodontist 78: 357–360

Olsen M E, Bishara S E, Damon P, Jakobsen J R 1997 Evaluation of Scotchbond multipurpose and maleic acid as alternative methods of bonding orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 111: 498–501

Opinya G N, Pameijer C H 1986 Tensile bond strength of fluorosed Kenyan teeth using the acid etch technique. International Dental Journal 36: 225–229

Reynolds J R 1975 A review of direct orthodontic bonding. British Journal of Orthodontics 2: 171–178

Vicente A, Bravo L A, Romero M, Ortíz A J, Canteras M 2004 Bond strength of brackets bonded with an adhesion promoter. British Dental Journal 196: 482–485

Vicente A, Bravo L A, Romero M, Ortíz A J, Canteras M 2006 Effects of 3 adhesion promoters on the shear bond strength of orthodontic brackets: an *in vitro* study. American Journal of Orthodontics and Dentofacial Orthopedics 129: 390–395

Weerasinghe D S, Nikaido T, Wettasinghe K A, Abayakoon J B, Tagami J 2005 Micro-shear bond strength and morphological analysis of a self-etching primer adhesive system to fluorosed enamel. Journal of Dentistry 33: 419–426

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