Effects of adhesion promoter on orthodontic bonding in fluorosed teeth: A scanning electron microscopy study

Aditi Gaur, Sandhya Maheshwari, Sanjeev Kumar Verma and Mohd. Tariq

ABSTRACT

Introduction: The objectives of the present study were to elucidate the effects of fluorosis in orthodontic bonding and to evaluate the efficiency of an adhesion promoter (Assure Universal Bonding Resin) in bonding to fluorosed teeth.

Materials and Methods: Extracted premolars were divided into two groups on the basis of Thylstrup and Fejerskov Index. Ten samples from each group were etched and evaluated for etching patterns using scanning electron microscope (SEM). The remaining samples were subdivided into four groups of 20 each on the basis of adhesives used: IA, IIA - Transbond XT and IB, IIB - Transbond XT plus Assure Universal Bonding Resin. Shear bond strength (SBS) was measured after 24 h using the universal testing machine. Adhesive remnant index (ARI) scores were recorded using SEM. Statistical analysis was conducted using a two-way analysis of variance, and Tukey's *post hoc* test was performed on SBS and ARI scores.

Results: Similar etching patterns were observed in both fluorosed and nonfluorosed teeth. No significant differences were found in the SBS values observed in both groups (8.66 ± 3.19 vs. 8.53 ± 3.44, $P = 1.000$). Increase in SBS was observed when Assure Universal Bonding Resin was used. Higher ARI scores were observed when adhesion promoter was used for bonding.

Conclusions: Mild-moderately fluorosed teeth etch in a manner similar to the nonfluorosed teeth. Similar bond strengths were achieved in fluorosed and nonfluorosed teeth when conventional composite was used. Use of adhesion promoter increases the bond strengths in both groups of teeth.

Key words: Bond strength, bonding, enamel damage, fluorosed, scanning electron microscopy

INTRODUCTION

Dental fluorosis is a developmental disturbance of enamel caused by exposure to high concentration of fluoride during the development of teeth which results in pathological changes in the tooth structure.[1] Orthodontists working in the endemic fluorosis regions may encounter difficulties in performing routine bonding procedures in cases affected by this condition. It is difficult to bond attachments to fluorosed enamel because of the inability to achieve a uniform etched surface.[2] The reduction in acid solubility of enamel has been attributed to the incorporation of fluoride in the enamel crystals during the developmental stages of teeth resulting in larger apatite crystals.[3]

Rebonding of brackets is a time-consuming procedure causing a negative impact on successful orthodontic treatment. Over the years, numerous modalities have been introduced to improve the bond strengths of the attachments to the tooth surfaces.

Adhesion promoters were originally introduced as bi-functional monomers such as 4-methacryloxyethyl trimellitate anhydride with both hydrophobic and hydrophilic groups promoting infiltration of

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Access this article online	
Quick Response Code:	Website: www.jorthodsci.org
	DOI: 10.4103/2278-0203.186165

How to cite this article: Gaur A, Maheshwari S, Verma SK, Tariq M. Effects of adhesion promoter on orthodontic bonding in fluorosed teeth: A scanning electron microscopy study. J Orthodont Sci 2016;5:87-91.

monomers into the hard tissue.[4] The penetration of monomers into the etched improve the enamel and their polymerization *in situ* has been suggested to adhesion to tooth surface.[5] It has been advocated that this form of chemical adhesion to enamel results in reduced microleakage and a superior hermetic seal.[6]

The use of such adhesion promoting materials although may be beneficial in terms of bond strength, they might lead to enamel damage during the debonding process. Such effects may be pronounced in fluorosed teeth owing to the weaker nature of the enamel of such teeth.[7] Thus, it is imperative to evaluate both the advantages and disadvantages of these newer materials.

The objectives of the present study were to elucidate the effects of fluorosis in orthodontic bonding and to evaluate the efficiency of an adhesion promoter (Assure Universal Bonding Resin) in bonding to fluorosed teeth.

MATERIALS AND METHODS

The aims of the present study were to evaluate the etching patterns in fluorosed and nonfluorosed teeth and to compare shear bond strength (SBS) using conventional composite versus an adhesion promoter with conventional composite in both groups. The enamel surface after debonding of brackets was evaluated using adhesive remnant index (ARI) scores in both groups.

The tooth samples used in the present study were obtained after extractions advised during routine orthodontic procedures with the patients' informed consent. Patients' history and clinical examination was done prior to the extractions to identify the cases with dental fluorosis. Teeth with Thylstrup and Fejerskov Index (TFI) score = 3–4 were selected as fluorosed teeth. After screening, a total of 100 premolars, out of which 50 fluorosed and 50 nonfluorosed teeth were selected for the present study. The teeth were stored in distilled water at room temperature until the testing procedures were applied. The distilled water was frequently replaced to prevent bacterial proliferation.

Preparation of Samples for Evaluation of Etching Pattern

Out of the selected tooth samples twenty teeth, ten nonfluorosed (Group I, TFI = 0) and ten fluorosed (Group II, TFI = 3–4) were separated for the evaluation of the etching patterns.

Etching Protocol

Group I (Thylstrup and Fejerskov Index = 0) and Group II (Thylstrup and Fejerskov Index = 3–4)

The teeth were polished (for 10 s) with pumice solution to clean the enamel surface. The enamel surface was etched for 30 s with 37% phosphoric acid liquid etchant. The etchant was rinsed off for 30 s with water. The etched surface was dried with clean oil-free and water-free air for 20 s.

Examination Under Scanning Electron Microscope

The teeth with etched enamel were sectioned mesiodistally using a diamond disk from the occlusal surface up to cement-enamel junction. The buccal half of the teeth was separated for evaluation under a scanning electron microscope (SEM). The sectioned surface of the sample was made flat to be adapted on the copper stub of SEM. The buccal surfaces of the sectioned samples were sputter coated with a gold-palladium layer to improve the conductivity of the observed surface during scanning. The samples were then evaluated under a SEM (JEOL, JSM-6510 series) with magnification ranging from × 5 to × 300,000 [Figure 1].

Images were recorded to evaluate the etching patterns at × 750 and ×2000 magnification. The photomicrographs were evaluated for various etching patterns according to 5-point scale by Silverstone *et al*.[8] The various etching patterns observed have been shown in Figure 2.

Shear Bond Strength Testing

Bonding protocol

The two groups of teeth were subdivided into four different groups based on the adhesives used for bonding of brackets:

- Group IA: Nonfluorosed teeth with conventional bonding adhesive (Transbond XT adhesive and primer)
- Group IB: Nonfluorosed teeth with conventional (Transbond XT) adhesive plus adhesion promoter (Assure Universal Bonding Resin)
- Group IIA: Fluorosed teeth with conventional bonding adhesive (Transbond XT adhesive and primer)
- Group IIB: Fluorosed teeth with conventional (Transbond XT) adhesive plus adhesion promoter (Assure Universal Bonding Resin).

Group IA, IIA

Enamel surface was etched for 30 s, and the etchant was rinsed off the tooth surface for 30 s. The etched surface was dried followed by the application of Transbond XT sealant over

Figure 1: Scanning electron microscope

the etched area. Transbond XT adhesive paste was applied directly on the bracket base and placed on tooth surface. The adhesive was cured for 30 s.

Group IB, IIB

The enamel surface was etched for 30 s, and the etchant was rinsed off by water followed by drying for 20 s. After drying, 2–3 layers of Assure Universal Bonding Resin were applied to the etched enamel for 15 s using an applicator. Then, it was gently air thinned for 5 s to evaporate the solvents. The brackets were bonded to the tooth surface using Transbond XT composite and cured for 30 s.

Debonding Procedure: Bond Strength Testing

The tooth samples after bonding were kept in distilled water for 24 h. Debonding and SBS testing was performed 24 h after the bonding procedure using a digital universal testing machine. The specimen was clamped in the attachment and a tangential load using a knife-edge blade was used to produce a direct force at a crosshead speed of 1 mm/min. The debonding force was directed parallel to the bracket/adhesive interface. The load was measured in Newtons. The values obtained were divided by the bracket base area, which was 9.61 mm^2 (measured using the scanning electron image of the bracket base), to obtain SBS in megapascal.

Examination of Enamel Surface Following Debonding

After debonding, all samples were examined under a SEM (JEOL, JSM-6510 series) which has a magnification ranging from × 5 to × 300,000. The adhesive remaining on the enamel surface was evaluated using the criteria proposed in the ARI of Artun and Bergland.[9]

Statistical Analysis

Statistical analysis was performed on SPSS software (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago, SPSS Inc.). Data were summarized as mean ± standard deviation. The groups were compared by two-way analysis of variance, and the significance of mean difference within and between the groups was evaluated by Tukey's *post hoc* test after ascertaining normality by Shapiro and Wilk test and homogeneity of variances by Levene's test. Categorical groups were compared by Chi-square test. A $P < 0.05$ was considered statistically significant.

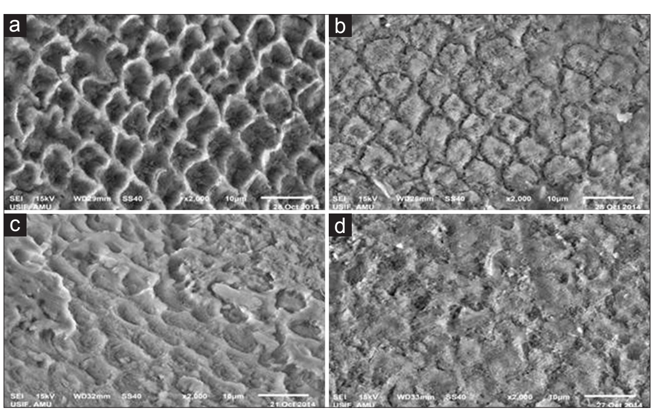

Figure 2: (a) Type I etching pattern, (b)Type II etching pattern, (c) Type III etching pattern, (d) Type IV etching pattern

RESULTS

Chi-square test revealed similar frequency of etching patterns in both groups and are presented in Table 1 [Figure 3].

Tukey test revealed similar SBS in both groups when Transbond XT was used as an adhesive (8.66 ± 3.19 vs. 8.53 ± 3.44, $P = 1.000$) Table 2, [Figure 4].

Significantly different and 29.9% higher SBS was seen in nonfluorosed teeth with Assure as compared to nonfluorosed teeth with Transbond XT (8.66 ± 3.19 vs. 12.36 ± 3.44, $P = 0.006$). Further, the mean SBS in fluorosed teeth with Assure was found significantly different and 27.1% higher as compared to fluorosed teeth with Transbond XT (8.53 ± 3.44 vs. 11.71 ± 3.67, $P = 0.024$) Table 2, [Figure 5].

The mean ARI score of nonfluorosed teeth with Assure was the highest followed by fluorosed teeth with Assure, nonfluorosed

Table 1: Frequency of etching patterns

Etching pattern	Teeth groups (*n*=10) (%)		χ^2 (df=3)	*P*
	Nonfluorosed teeth	Fluorosed teeth		
Type I	2 (20.0)	2 (20.0)	2.79	0.426
Type II	5 (50.0)	3 (30.0)		
Type III	2 (20.0)	5 (50.0)		
Type IV	1 (10.0)	0 (0.0)		

Table 2: Shear bond strength (megapascal) (mean±standard deviation, *n*=20) of two teeth groups and two adhesive groups

Adhesive groups	Teeth groups		*P*
	Nonfluorosed teeth	Fluoro sed teeth	
Transbond XT	8.66±3.19 (7.16-10.15)	8.53±3.44 (6.93-10.14)	1.000
Assure	12.36±3.44 (10.75-13.97)	11.71±3.67 (9.99-13.43)	0.932
P	0.006	0.024	-

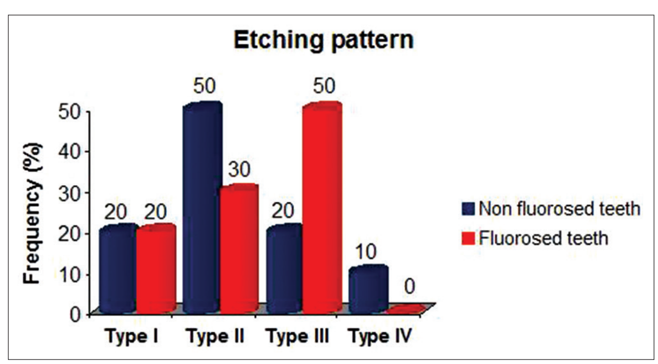

Figure 3: Distribution of etching patterns of two teeth groups

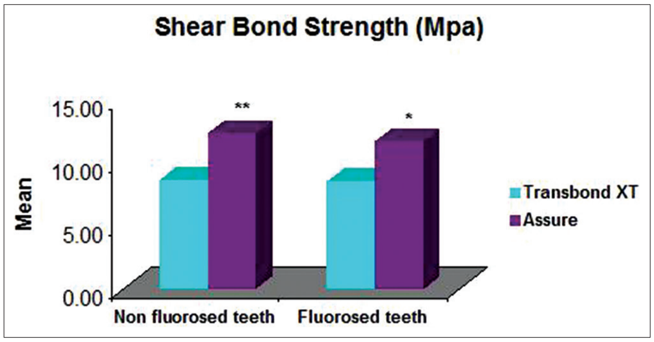

Figure 4: For each teeth type, bar graphs showing mean shear bond strength between the groups

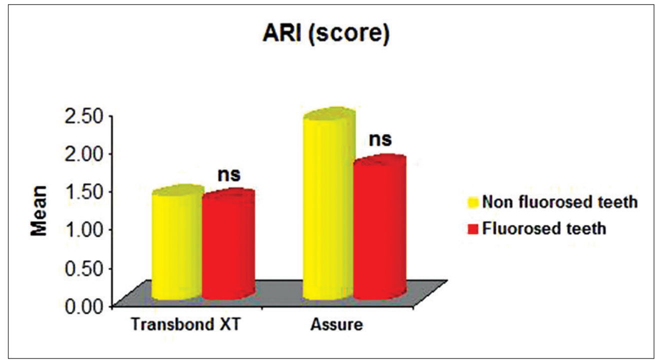

Figure 5: For each adhesive, bar graphs showing mean adhesive remnant index score between the teeth types

teeth with Transbond XT, and fluorosed teeth with Transbond XT the least as shown in Figure 5. Pearson correlation analysis showed a significant and positive (direct) correlation between ARI score and SBS ($r = 0.39$, $P < 0.001$) indicating that as ARI score increase SBS may also increase.

DISCUSSION

The present study was designed to evaluate the difference in the etching of fluorosed and nonfluorosed enamel and the effectiveness of adhesion promoter in improving the bond strength in fluorosed teeth when compared with nonfluorosed teeth.

The photomicrographs obtained after etching revealed clearly discernible etching patterns in both nonfluorosed and fluorosed teeth when etched for 30 s. There was no statistically significant difference found in the etching patterns between the two groups. Opinya and Pameijer have recommended increased etching time with 37% phosphoric acid for fluorosed teeth.[2] Al-Sugair and Akpata in their investigation of etching pattern of fluorosed teeth suggested an etching time of 30 s for fluorosed teeth with TFI = 4 and 90 s for severely fluorosed teeth. It was also reported that enamel specimens with TFI score (0–3) were not significantly different from each other after 37% phosphoric acid application.[10] Recent studies have shown no differences between the etch patterns of fluorosed and nonfluorosed teeth when etched for variable time periods.[11,12]

The SBS of nonfluorosed and fluorosed teeth was found to be comparable. The SBS values in the present study were found to be above the clinically acceptable range in both fluorosed and nonfluorosed teeth.

Adanir *et al*. demonstrated in their *in vitro* study while using conventional composite for bonding on fluorosed teeth that the bond strengths of composites with fluorosed teeth were low, but still lied in the clinically acceptable range.[13] Several previous studies have shown similar results and no differences between the bond strengths of fluorosed and nonfluorosed teeth.[10,14,15]

Adhesion boosters have been advocated as means to enhance the bonding of composites to the enamel. Adhesion promoters were introduced as agents containing bifunctional molecules which promote the infiltration of monomers into the etched surface. These bond improving agents have been tested in various conditions where conventional methods failed to provide the desired results. The presently used adhesion promoters comprise an aqueous solution of hydroxyethyl methacrylate and ethanol or acetone, which help in moisture control and provide a strong adhesive bond. Assure Universal Bonding Resin is one such agent, which has been suggested to improve the bonding to brackets during orthodontic procedures. According to the manufacturers, Assure can be used to enhance the bond strengths in difficult enamel conditions such as fluorosed enamel, deciduous teeth, metal surfaces, and porcelain. Moreover, bonding with Assure does not require the use of a separate bonding agent before its application, thus eliminating an extra step during the bonding procedure.

The effectiveness of adhesion promoters on fluorosed teeth was shown by Adanir *et al*. suggesting that fluorosis reduces the bond strength of orthodontic brackets and when an adhesion booster is used as a bonding agent, there is a significant increase in the bond strength to fluorosed teeth.[13] Noble *et al*. conducted an *in vivo* study and evaluated the effectiveness of an adhesion promoter in fluorosed dentition. Their results showed that reduced bond failures were observed during the 9 months observation period of their study.[6] The results of the present study were similar to the previous studies involving the evaluation of adhesion promoters to increase the bond strengths in normal conditions as well as clinically challenging situations such as fluorosis.

Adhesive remnants and any enamel damage were observed on the tooth surfaces using the SEM and evaluated according to the ARI scores by Artun and Bergland.[9] Bracket failure in most cases, is a combination of both adhesive and cohesive failures, i.e., a mixed failure.[16] When there is a bond failure at the adhesive-enamel junction, some enamel loss always occurs because of the micromechanical bond between the composite and the enamel surface. The bond failure at the bracket – adhesive junction or a cohesive failure in the adhesive indicates a lesser possibility of damage to the enamel while debonding brackets.

Figure 6: Enamel damage in a fluorosed tooth

In this study, the overall ARI scores were found to be significantly high in the group with nonfluorosed teeth when bonded using Assure. These findings were contrary to those suggested by Adanir *et al*. according to which bond failure with an adhesion promoter occurred more at the adhesive enamel interface.

Greater frequency of adhesive remnant on the tooth surface might indicate enamel protection during the debonding process but greater chances of damage during the clean-up procedure.[17] In the present study, greater adhesive remnant on the tooth surface was shown, and it could be suggested that the adhesion promoter led to better adherence of the adhesive to the enamel surface as compared to the bracket surface and thus would result in overall reduced enamel damage.

A single sample of the fluorosed teeth group bonded with the adhesion promoter was observed with damage to the enamel surface [Figure 6]. This might be due to the weak superficial enamel layer as the bond strength in this sample was similar to other samples.

This study highlighted the bond enhancing properties of adhesion promoters, and it has been shown that these agents are effective in increasing the bond strengths along with ensuring minimal enamel damage. Thus, such bond enhancers can be recommended to be used in clinical settings to improve the quality of orthodontic care.

CONCLUSIONS

- No significant difference was found between the etching patterns of nonfluorosed and fluorosed teeth when etched with 37% phosphoric acid for 30 seconds
- The SBS in fluorosed and nonfluorosed teeth were comparable when conventional composite was used
- Assure adhesion promoter increased the bond strengths in both nonfluorosed and fluorosed teeth
- The bond failure occurred at a more favorable location, i.e., adhesive enamel interface, when an adhesion promoter was used.

Financial Support and Sponsorship

Nil.

Conflicts of Interest

There are no conflicts of interest.

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