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Original Article

Does chlorhexidine affect the shear bond strengths of orthodontic brackets?

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Abstract *Background/purpose:* The purpose of this study was to examine the effect of 1% chlorhexidine (CHX) gel on the shear bond strength (SBS) of orthodontic brackets bonded with Transbond XT (XT, 3M Unitek) and Transbond Plus Self-Etching Primer (TSEP, 3M Unitek).
Materials and methods: In total, 75 extracted premolars were collected and randomly divided into five groups of 15 teeth each. Brackets were bonded to teeth using a different experimental technique for each group as follows: (I) (control): etch/dry/Transbond XT; (II) CHX gel/etch/dry/Transbond XT; (III) etch/dry/CHX gel/Transbond XT; (IV) dry/TSEP; and (V) CHX gel/dry/TSEP. All products were used according to the manufacturers' instructions. An Instron Universal Testing Machine was used to directly apply an occlusal shear force onto the enamel-bracket interface at a speed of 0.5 mm/min. Residual adhesive on each tooth was evaluated using an adhesive remnant index (ARI). Analysis of variance was used to compare the SBS of the groups, and a Chi-squared test was used to compare ARI scores.
Results: Group I had the highest mean SBS (16.47 $\pm$ 4.2 MPa), followed by Groups II (16.24 $\pm$ 4.5 MPa), III (13.08 $\pm$ 4.50 MPa), IV (11.95 $\pm$ 2.7 MPa) and V (11.16 $\pm$ 2.8 MPa). No statistical differences were observed between Groups I and II ($P > 0.05$) or between groups IV and V ($P > 0.05$). However, SBS scores for Groups IV and V were significantly lower than those of Groups I and II ($P > 0.05$). No significant difference was observed in ARI scores among any of the groups ($P > 0.05$). Prior application of CHX gel did not significantly affect the SBS of orthodontic bonding adhesives.

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Conclusions: CHX gel is thought to obviate initial caries lesions during fixed orthodontic treatment.

Introduction

Conventional adhesive systems are capable of adequately bonding orthodontic brackets to enamel; however, the procedure is technique-sensitive and time consuming.[1,2] For this reason, research has focused on reducing the number of conditioning steps to simplify the technique and decrease the amount of enamel loss associated with etching.[3] The development of self-etching primer/adhesive systems that combine acid etching, rinsing, and priming has revolutionized clinical orthodontic practice.[3,4] Furthermore to simplify the bonding procedure, the combination of etching, rinsing, and priming saves clinician chair-side time,[5,6] while still providing acceptable clinical retention rates.[7]

Decalcification and periodontal problems are common iatrogenic side effects of orthodontic treatment. White-spot lesions, which most often develop in the gingival region and adjacent to orthodontic brackets,[8] leave enamel susceptible to caries attack.[9,10] The risk of decalcification associated with fixed orthodontic appliances was reported to vary from as little as 2% to as much as 96%,[11–13] depending on the presence of decalcification before treatment, the use of fluoride supplements during treatment, and the methods used to assess and score decalcification.[8] Caries and decalcification can be greatly reduced by maintaining good oral hygiene, applying topical fluoride, and using fluoride-containing toothpaste during orthodontic treatment.[14–17] However, according to Ogaard et al., in the face of a severe cariogenic challenge, even fluoride may have limited effective success in preventing decalcification.[17] Therefore, the use of additional antibacterial agents such as xylitol, triclosan, and chlorhexidine (CHX) in conjunction with fluoride was reported.[17,18]

CHX, an antibacterial and antiseptic agent widely used in dentistry,[19] is the most potent documented antimicrobial agent against mutans streptococci and dental caries. Both short-[20] and long-term [21,22] studies showed CHX to effectively control plaque and gingivitis without the formation of resistant organisms in the oral flora. The most widely used forms of CHX are 1% and 2% gels. Furthermore there are mouthwash and solution forms of CHX.[23]

A previous *in vitro* study[23] assessed the effects of various CHX applications on the shear bond strength (SBS) of orthodontic bracket adhesives. The aim of the present *in vitro* study was to evaluate the effect of 1% CHX gel on the SBS of two different orthodontic primers (Transbond XT and Transbond Plus Self-Etching Primer, both from 3M Unitek, Monrovia, CA, USA).

Materials and methods

The study was conducted using 75 caries- and restoration-free human maxillary premolars. Teeth that had hypoplastic enamel, fractures, or caries were excluded. Teeth were rinsed in water to remove any traces of blood and then disinfected in a 0.1% Thymol solution. All enamel surfaces were examined under a binocular stereomicroscope at ×10 magnification (Celestron, LLC. Torrance, CA, USA, for stereo (3D) viewing), and any teeth with hypoplastic enamel, fractures, or caries were excluded. Teeth were stored in distilled water that was changed daily until use. Each tooth was mounted in a 3-cm diameter mold using chemically cured acrylic resin (Vertex, Zeist, the Netherlands), with the labial surface oriented so that it was parallel to the shear force during bond-strength testing. Teeth were randomly divided into five groups of 15 specimens each according to bonding treatment, as follows: Group I consisted of phosphoric acid etching + Transbond XT primer; Group II consisted of 1% CHX gel + phosphoric acid etching + Transbond XT primer; Group III consisted of phosphoric acid etching + 1% CHX gel + Transbond XT primer; Group IV consisted of Transbond Plus Self-Etching Primer; and Group V consisted of 1% CHX gel + Transbond Plus Self-Etching Primer.

Orthodontic metal brackets (Generus Roth; GAC International, Bohemia, NY, USA) with a base area of approximately 12.35 mm^2 were used to bond all teeth. Details of the bonding procedures are given in Table 1. After bonding, all samples were light-cured with an LED unit (Elipar Freelight, 3M ESPE, Seefeld, Germany) for 20 seconds and stored in distilled water at 37°C for 24 hours before SBS testing. The SBS was determined by mounting a sample on a Universal Testing Machine (Instron, Testometric, Lancheire, UK) with the bracket base parallel to the direction of the force, which was applied in an occlusogingival direction at a cross-head speed of 0.5 mm/min until fracture, i.e., until the bracket was dislodged. Bond strength was recorded in Newtons (N) and was converted to megapascals MPa.[23]

Examination of fracture sites

Brackets and enamel surfaces were examined under a stereomicroscope at ×10 magnification (Celestron, LLC, Torrance, CA, USA), and any remaining adhesive was assessed and recorded using a modified adhesive remnant index (ARI), as follows: 0, no adhesive remaining on the tooth (failure between the adhesive and enamel); 1, less than half of the adhesive remaining on the tooth; 2, more than half of the adhesive remaining on the tooth; and 3, all of the adhesive remaining on the tooth, with an impression of the bracket mesh.[24]

Statistical analysis

Descriptive statistics, including the mean, standard deviation, and minimum and maximum stress values were calculated for each group, and significant differences were

Table 1 Bonding procedures.

Groups	Application procedure
Group I: Phosphoric acid etching + Transbond XT primer	Step 1. Teeth etched with 37% phosphoric acid gel for 30 s Step 2. Washed for 20 s and gently dried for 10 s Step 3. Thin coat of primer applied to tooth Step 4. Adhesive applied to bracket base Step 5. Bracket seated and positioned on tooth
Group II: 1% CHX gel + phosphoric acid etching + Transbond XT primer.	Step 1. CHX gel applied to enamel for 20 s Step 2. Dried for 30 s before etching Step 3. Wait for 20 s Step 4. Teeth etched with 37% phosphoric acid gel for 30 s Step 5. Washed for 20 s and gently dried for 10 s Step 6. Thin coat of primer applied to tooth Step 7. Adhesive applied to bracket base Step 8. Bracket seated and positioned on tooth Step 9. Light-cured with LED for 20 s
Group III: Phosphoric acid etching + 1% CHX gel + Transbond XT primer.	Step 1. Teeth etched with 37% phosphoric acid gel for 30 s Step 2. Washed for 20 s and gently dried for 10 s Step 3. CHX gel applied over enamel for 20 s Step 4. Dried for 30 s Step 5. Thin coat of primer applied to tooth Step 6. Adhesive applied to bracket base Step 7. Bracket seated and positioned on tooth
Group IV: Transbond Plus Self-Etching Primer	Step 1. Pressed the compartment 1 Step 2. Folded the black chamber onto the white chamber Step 3. Pressed on the chambers Step 3a. Spined or churned applicator to mix adhesive Step 4. Adhesive applied to enamel Step 5. Wait 5 s Step 6. Gently but thoroughly air-dried to remove aqueous solvent Step 7. Adhesive applied to bracket base Step 8. Bracket seated and positioned on tooth
Group V: 1% CHX gel + Transbond Plus Self-Etching Primer	Step 1. CHX gel applied over enamel for 20 s Step 2. Dried for 30 s before etching Step 3. Wait for 20 s Step 4. Pressed the compartment 1 Step 5. Folded the black chamber onto the white chamber Step 6. Pressed on the chambers Step 6a. Spined or churned applicator to mix adhesive Step 7. Adhesive applied to enamel Step 8. Wait 5 s Step 9. Gently but thoroughly air-dried to remove aqueous solvent Step 10. Adhesive applied to bracket base Step 11. Bracket seated and positioned on tooth

CHX = chlorhexidine; LED = light emitting diode.

assessed using one-way analysis of variance (ANOVA) and Tukey's tests, with the level of significance set at $P < 0.05$. Differences in ARI scores among groups were assessed and identified using a Chi-squared test.

Scanning electron microscopic observations

After fracture, one specimen from each group randomly selected for an Scanning electron microscopic (SEM) evaluation. All specimens were cleaned in distilled water with ultrasonic agitation for 30 minutes and gently air-dried. They were then affixed to SEM stubs, coated with gold, and observed under an SEM (JSM-5600, JEOL, Tokyo, Japan) at $\times$1500 magnification (Fig. 1). Representative images of the different surface treatments were captured digitally and stored in computer files.

Results

Shear bond strength

Descriptive statistics for SBS are shown in Table 2. Statistically significant differences in SBS were found among the

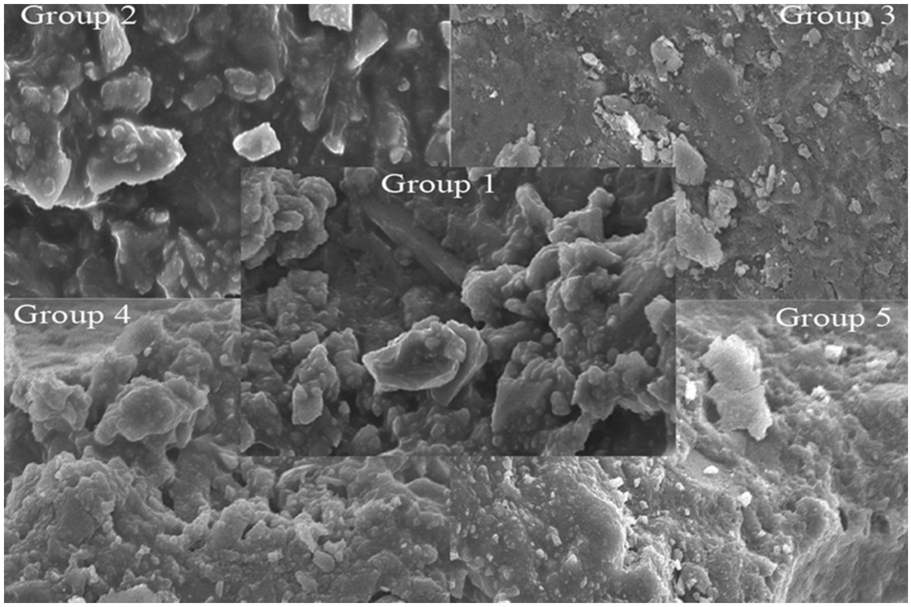

Figure 1 SEM images of the experimental groups (1500 × magnification).

groups ($P < 0.001$). Groups I and II showed higher average bond strength values (16.47 MPa for Group I and 16.24 MPa for Group II) than Groups III, IV, and V (13.08 MPa). The results of the one-way ANOVA indicated no significant difference in the SBS among Groups III, IV and V, as presented in Table 2 ($P = 0.800$). There was no significant difference between Groups IV (11.95 ± 2.7 MPa) and V (11.16 ± 2.73) ($P > 0.05$). All adhesive groups had mean SBS values of >10 MPa.

ARI scores

The results of the ARI scores are shown in Table 3. A comparable distribution of ARI scores of 1, 2, and 3 was observed. Group I had a greater frequency of ARI scores of 2 and 3 (bracket-adhesive interface). For Groups II and III, a higher frequency of an ARI score of 3 was recorded. Thus, bond failure was within the adhesive or at the adhesive-bracket interface. No significant differences in ARI scores were found among the five groups ($P = 0.57$). In Groups I, II, and V, ARI scores of 0 were not observed, whereas groups III and IV showed ARI scores of 0.

Table 2 Results of the one-way analysis of variance and mean shear bond strengths and SDs.

Group	Mean	SD	F value	P value
			14.211	<0.001
Group I	16.47	4.15		
Group II	16.24	3.99		
Group III	13.08	4.50		P = 0.800 for
Group IV	11.95	2.70		Groups III, IV, and V
Group V	11.16	2.73		

SD = standard deviation.

Discussion

Conventional methods used to bond orthodontic brackets to teeth rely on acid-etching for adequate retention. However, enamel etching with phosphoric acid creates an etched pattern characterized by surface irregularities and areas of demineralization,[25,26] making the enamel more susceptible to caries attack, especially with fixed orthodontic appliances. Self-etching primers are thought to have several benefits over traditional acid-etching adhesive systems, including reduced chair time,[24] simpler application procedures, resulting in fewer procedural errors, such as contamination with saliva and water,[4] and reduced susceptibility to caries attack because of minimized demineralization.[27]

Previous studies comparing conventional and self-etching primers reported different results. Whereas some studies[1,27–30] showed significantly lower bond strengths for self-etching adhesives compared with conventional

Table 3 Frequency distribution and Chi-squared results for ARI scores of groups ARI scores: 0, no adhesive remaining on tooth; 1, less than half of enamel bonding site covered with adhesive; 2, more than half of enamel bonding site covered with adhesive; 3, enamel bonding site covered entirely with adhesive.

Group tests	ARI Scores			
	0	1	2	3
Group I	—	2	6	7
Group II	—	2	2	11
Group III	1	2	2	10
Group IV	1	2	3	9
Group V	—	2	3	10

ARI = adhesive remnant index.

adhesives, others found self-etching adhesives had higher[31] or similar[29,32–35] bond strengths compared with conventional adhesives.

Overall, the mean bond strengths recorded in the present study were higher (11.16–16.47 MPa) than those previously reported (6.0–8.0 MPa).[36] Differences in the adhesive thickness among studies might account for the differences in mean SBS values.

Under dry conditions, self-etching primers show a significantly superior performance to conventional bonding.[31] Self-etching primers display adequate bond strength under both dry conditions and when contaminated with 1% CHX gel; however, there was a significant difference when comparing median bond strengths under dry and contaminated conditions. Other studies using self-etching primers on enamel showed that they offered clinically adequate bond strength but were inferior to conventional primers.[27–29] However, those studies compared these materials only under dry conditions and not on wet or contaminated enamel. The results of this study proved that self-etching primers offered adequate bond strength under both dry and contaminated conditions. However, the bond strength was significantly reduced in the presence of contamination.

Failure at the bracket-adhesive interface (ARI $= 3$) occurred at significantly higher rates than other types of bond failure for all adhesive protocols tested in the present study. This finding is in line with those of previous studies.[29] Bishara et al.[37] maintained that bond failure at the bracket-adhesive interface or within the adhesive was more desirable and safer than failure at the adhesive-enamel interface because enamel fracture and crazing were reported at the time of bracket debonding.

Plaque retention and the risk of subsequent caries development are major problems associated with treatment using fixed orthodontic appliances. Significant increases in salivary and *Streptococcus mutans* levels are seen as early as the first week after placement.[21,22] Microleakage may provide a continual food supply allowing various pathogens to exist underneath the orthodontic brackets. This area provides a convenient niche for the survival and reproduction of existing bacteria, thus increasing acidity levels and promoting the development of caries. As reported by Bürgers et al.[38] and Kervanto-Seppälä et al.,[39] despite acid-etching and rigorous washing procedures, viable bacteria can be observed even 5–10 years after the placement of resin fissure sealants. Such examples suggest a high risk of caries developing beneath retained brackets during orthodontic treatment. Given the association between these organisms and the initiation and development of caries, especially at retentive tooth sites, the use of a chemical agent to reduce bacterial plaque accumulation and thus the incidence of caries during the active phase of orthodontic treatment would be of great clinical benefit.

Wirthlin recommend the use of sterile saline or sterile water as a coolant/irrigant for decontamination; however, in some cases, dental units are supplied by tap water, which can contaminate disinfected enamel.[40] A previous *in vitro* study by the present authors[41] recommended the use of a disinfectant solution to eliminate residual bacteria after cavity preparation, despite the ability of acid-etching to reduce bacteria along the cavity walls. The use of antibacterial agents such as xylitol, triclosan, and CHX in conjunction with fluoride agents and intensive oral-hygiene instructions was also suggested as a means of reducing the risk of decalcification and subsequent caries development.[17,18] However, no data were published concerning the effects of 1% CHX gel on the SBS of self-etching or conventional acid-etching primers.

An earlier study showed CHX to have a strong affinity for tooth surfaces and that this affinity increased with acid etching,[42] suggesting that CHX application could improve adhesive bond strengths.[41] In fact, although the present study found the application of 1% CHX gel before acid-etching had no effect on the SBS of a conventional primer (Transbond XT), the application of 1% CHX gel after acid-etching was shown to reduce the SBS of conventional bonding adhesive to orthodontic brackets. The application of 1% CHX gel in combination with a self-etching primer (Transbond Plus) had no effect on SBSs.

Using CHX gel is thought to obviate initial caries lesions during fixed orthodontic treatment. However, long-term clinical studies are still needed to determine the effects of CHX gel.

Conclusions

The SBSs of all groups exceeded the minimum clinically acceptable values of 6–8 MPa. SBSs of acid-etching systems were significantly higher than those of self-etching adhesive systems, regardless of whether 1% CHX gel was applied. CHX gel application before bonding may be recommended in patients being treated with fixed orthodontic appliances.

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