ABSTRACT

Context: The detrimental effect of moisture on orthodontic bonding has long been known. Hydrophilic bonding materials have been introduced suggesting the possibility of obtaining successful orthodontic bonding to a moisture contaminated enamel surface.

Aims: This study has been performed with an aim to compare the in vitro shear bond strength (SBS) and debonding characteristic of moisture-insensitive primer (MIP) (Transbond MIP) (3M Unitek, South Peck Road, Monrovia, California, USA) and self-etching primer (SEP) (Transbond Plus SEP) (3M Unitek, South Peck Road, Monrovia, California, USA) in combination with a color changing adhesive system (Transbond Plus Color Change) (3M Unitek, South Peck Road, Monrovia, California, USA) under both dry and contaminated condition.

Settings and Design: Randomized controlled clinical study.

Subjects and Methods: One hundred and twenty freshly extracted teeth for the purpose of orthodontic treatment were collected. Teeth were randomly assigned into four groups, each consisting of 30 specimen and stainless steel brackets were bonded using each primer-adhesive combination under different enamel conditions, that is, dry and enamel contaminated with natural saliva. SBS and adhesive remnant index were calculated for each group.

Results: Analysis of variance of SBS for both MIP and SEP under dry and contaminated condition showed no statistical significance ($P = 0.5$). Chi-square test showed significant difference in debonding characteristics among the test groups ($P < 0.001$). All the groups showed typical debonding characteristics of separation either at the bracket-adhesive interface or within the adhesive itself.

Conclusions: Moisture contamination did not affect the SBS and adhesive remaining on tooth for both MIP and SEP.

Key words: Moisture contamination, moisture-insensitive primer, orthodontic bonding, self-etching primer

INTRODUCTION

Successful bonding of orthodontic attachments to acid-etched enamel influences the treatment results to a great extent. Bond failure during orthodontic treatment is relatively frequent and undesirable, is costly in terms of time, material, and patient convenience.

Zachrisson,[1] cited contamination as an important cause of bond failure. Traditional bonding systems demand completely dry and isolated fields to obtain clinically acceptable bond strength. However, various clinical conditions do not permit ideal isolation in the bonding site. It is suggested that even momentary saliva or blood contamination adversely affects the bond, because saliva and blood deposit organic adhesive coatings that resist washing in the first few seconds of exposure.[2] The detrimental effect of moisture on orthodontic bonding may relate to water adsorption, which release by-product such as formaldehyde so producing a plasticizing effect.[3]

To address this reality, hydrophilic bonding materials have been developed. The fourth-generation bonding system, the moisture-insensitive primers (MIPs), and the fifth-generation bonding systems, that is, self-etching primer (SEP) are hydrophilic in nature.
Although, literatures exist that compares the shear bond strength (SBS) of these two novel orthodontic primer systems, very few studies have been done so far comparing the performance of these two primers along with a newly introduced color changing adhesive that has also been claimed to be hydrophilic in nature.

Therefore, this study has been performed with an aim to compare the in vitro SBS and debonding characteristics of MIP and SEP in combination with a color changing adhesive system under both dry and contaminated condition.

**SUBJECTS AND METHODS**

After obtained informed consent from the patient, around 250 human premolar teeth extracted for the purpose of orthodontic treatment were collected. Teeth with enamel hypoplasia, caries, restoration, cracks on enamel surface, enamel surface that has been previously treated with chemical agent were excluded from the study. Following the exclusion criteria, 120 premolar teeth were selected for the study. Collected teeth were rinsed thoroughly under water, placed in 0.1% thymol solution for 1 week followed by storage in distilled water at 4°C for not >1 month according to international standards (ISO 11405/2003) for testing of adhesion to tooth structure. Teeth were fixed in self-cure acrylic block (30 mm × 25 mm × 15 mm). Roots remained completely embedded in acrylic block up to cemento-enamel junction. Each tooth has been oriented with the help of dental surveyor, so that the buccal surface remained parallel to the applied force during SBS test. All of the teeth were randomly assigned into four groups, that is, Groups I-IV each consisting of 30 specimen. Acrylic blocks have been color coded to identify each test groups [Figure 1]. Sample size was determined to have adequate power of (80%) and statistical significance at P < 0.05.

Buccal surfaces of the teeth were cleaned using a slurry of nonfluoridated pumice powder and water using rubber cup for 10 s followed by rinsing with water spray and drying with compressed air for 30 s. Stainless steel premolar brackets without hook (0.022 MBT prescription, Gemini series, 3M Unitek, Monrovia, California, USA) were used to bond all the teeth.

Teeth in Groups I and III were etched with 35% phosphoric acid (Scotchbond, 3M ESPE) for 15 s followed by thorough washing and drying for 5 s to get a frosty white appearance. Transbond MIP (3M Unitek, Monrovia, California, USA) was applied onto the tooth surface in Group I. For teeth in Group III, etched teeth surface has been contaminated with saliva that was collected from the operator within an hour after brushing without any food consumed in between. Two coats of saliva applied on etched surface, excess was blotted followed by application of Transbond MIP primer, surface has been dried. Transbond Plus color change adhesive (3M Unitek, Monrovia, California, USA) was applied to the underside of the bracket base and placed in firm contact with the tooth surface. Adhesive is light cured using light emitting diode (Guilin Woodpecker Medical Instruments Co. Ltd, Guilin, China,) for 40 s (10 s from each side, i.e. mesial, distal, occlusal, gingival).

For Groups II and IV SEP, Transbond Plus SEP s (3M Unitek, Monrovia, California, USA) is rubbed on the enamel surface for 3 s followed by air thinning for 15 s. For Group IV, after application of SEP, teeth surface has been contaminated with saliva. Transbond Plus color change adhesive was applied to the underside of the bracket base and placed in firm contact with the tooth surface followed by light curing for 40 s.

Test specimens were immersed in distilled water at temperature of 37°C from the time of bonding until the SBS test performed (24 h). SBS was measured on universal testing machine (Instron, Model No 4444, Instron Corp., USA). Debonding procedure was done using a wire loop, made of rectangular stainless steel wire (0.018 × 0.025 inch) [Figure 2]. Debonding force was applied to the bracket in a gingivo-occlusal direction at a cross-head speed of 1 mm/min until bond failure occurred. Force values obtained in Newton was divided by the

![Figure 1: Test groups (colour coded for identification)](image1)

![Figure 2: Debonding procedure followed in the study](image2)
Debonded specimen was examined using a stereo microscope (Leica MZ-6) under 10x magnification and scoring was done using adhesive remnant index (ARI). For this study the Adhesive remnant index score followed is the original criteria established by Artun and Bergland. The descriptive statistics including the mean, standard deviation were calculated for SBS values. Statistical analysis was performed using the (SPSS software, version 16, IBM Corp., New York, USA). One-way analysis of variance (ANOVA) was selected to determine whether significant differences existed for SBS values among different groups. Significance level has been predetermined at the 95% confidence level ($P < 0.05$). The nonparametric ARI data has been analyzed using Chi-square test. Significance level has been predetermined at 0.001 significance level for ARI score.

**RESULTS**

Mean, standard deviation, statistical significance of SBS values for each of the groups evaluated [Table 1]. The results of the ANOVA indicated that there were no statistically significant differences ($P = 0.5$) in mean SBS values among different groups. Post-hoc significance obtained by Bonferroni correction showed no statistical significance ($P > 0.05$) for pair wise comparison of means [Table 2].

Chi-square analysis for ARI scores for the four different groups has been presented [Table 3]. Chi-square analysis of ARI score among the four groups tested showed high statistical significance ($P < 0.001$).

**DISCUSSION**

With the aim of improving the hydrophilic properties of traditional adhesives, the concept of wet bonding or bonding in moist environment was being introduced and was achieved in fourth-generation bonding systems. Fifth-generation bonding systems were developed to minimize steps and increase the reliability of bonding.

Acceptable bond strength from clinical point of view should be high enough so that inadvertent deboning during treatment should not occur, but low enough so that when debonded, it is easy to clean without damage to enamel. It has been postulated that an acceptable minimum tensile bond strength to etched enamel is in the range of 5.9-7.9 MPa. Nonetheless, the minimum bond strength value of 6-8 MPa for shear, shear-peel and tensile-peel is reported in most of the literature. Retief suggested that bond strength, in order to avoid enamel fractures to be as low as 13.8 MPa. SBS obtained in this study for both MIP and SEP under both dry and contaminated condition were well within the acceptable range of bond strength.

In this study, SBS of MIP and SEP under both dry and contaminated condition was statistically insignificant, which may be attributed to:

1. Moisture-insensitive primer are hydrophilic primer solution dissolved in solvents such as acetone or ethanol that might have imparted tolerance to moisture. In addition to micro-mechanical retention, a reversible hydrolytic bond mechanism can be established by breaking or reforming of carboxylate salt complexes formed between the ionized carboxyl groups of methacrylate functionalized-polyalkeonic acid co-polymer and residual enamel calcium. This mechanism might enhance their performance under contaminated condition

2. Self-etching primer contains methacrylated phosphoric acid esters as main ingredient. Chemical adhesion of SEP might explain their tolerance to moisture. Another possible explanation may be presence of water in its composition. Water is necessary to activate SEP and obtain adequate pH

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**Table 1: Mean, SD and statistical significance of SBS values of MIP (dry), transbond plus SEP (dry), MIP (contaminated) and transbond plus SEP (contaminated) group**

| Group        | SBS (in MPa) | Statistical significance value |
|--------------|--------------|-------------------------------|
|              | Mean         | SD                            |                             |
| MIP          |              |                               |                             |
| Dry          | 9.43         | 2.62                          | 0.500                       |
| Contaminated | 9.19         | 3.15                          |                             |
| Self-etch    |              |                               |                             |
| Dry          | 10.34        | 3.49                          |                             |
| Contaminated | 9.46         | 3.10                          |                             |

SD – Standard deviation; SBS – Shear bond strength; MIP – Moisture-insensitive primer; SEP – Self-etching primer
Table 2: Bonferroni correction for multiple comparison of mean SBS

| Multiple comparisons | Mean difference (I-J) | SE  | Statistical significance | 95% CI | Lower bound | Upper bound |
|----------------------|-----------------------|-----|--------------------------|--------|-------------|-------------|
| Self-etch (contaminated) | MIP (contaminated)   | 0.27333 | 0.80179 | 1.000 | -1.8789 | 2.4255 |
| Self-etch (dry)          | MIP (dry)            | -0.87667 | 0.80179 | 1.000 | -3.0289 | 1.2755 |
| MIP (contaminated)       | Self-etch (contaminated) | -0.27333 | 0.80179 | 1.000 | -2.1155 | 2.1889 |
| Self-etch (dry)          | MIP (dry)            | -1.15000 | 0.80179 | 0.925 | -3.3022 | 1.0022 |
| MIP (contaminated)       | Self-etch (contaminated) | -0.23667 | 0.80179 | 1.000 | -2.3889 | 1.9155 |
| Self-etch (dry)          | MIP (dry)            | 1.15000  | 0.80179 | 0.925 | -1.0022 | 3.3022 |
| MIP (contaminated)       | Self-etch (dry)      | 0.23667  | 0.80179 | 1.000 | -1.9155 | 2.3889 |
| Self-etch (dry)          | MIP (dry)            | -0.03667 | 0.80179 | 1.000 | -2.1889 | 2.1155 |

SE = Standard error; CI = Confidence interval; MIP = Moisture-insensitive primer; SBS = Shear bond strength

Table 3: Chi-square analysis for ARI score

| Group                  | ARI score | 0   | 1   | 2   | 3   | Total  |
|------------------------|-----------|-----|-----|-----|-----|--------|
| MIP (dry)              |           | 1   | 16  | 10  | 3   | 30     |
| Count                  | Percentage of total | 0.83 | 13.33 | 8.33 | 2.50 | 25.00 |
| Self-etch (dry)        |           | 1   | 12  | 16  | 3   | 30     |
| Count                  | Percentage of total | 0.83 | 0.83 | 10.00 | 16.00 | 25.00 |
| MIP (contaminated)     |           | 8   | 10  | 10  | 2   | 30     |
| Count                  | Percentage of total | 6.67 | 8.33 | 8.33 | 1.67 | 25.00 |
| Self-etch (contaminated)|   | 4   | 2   | 20  | 4   | 30     |
| Count                  | Percentage of total | 3.33 | 1.67 | 16.67 | 3.33 | 25.00 |
| Total                  |           | 14  | 29  | 52  | 25  | 120    |
| Percentage of total    |           | 11.67 | 24.17 | 43.33 | 20.83 | 100.00 |

The Chi-squared test showed significant differences between the site failure of different groups, P < 0.001. ARI = Adhesive remnant index; MIP = Moisture-insensitive primer

3. In addition to the hydrophilic primers, adhesive used in the present study, that is, Transbond Plus color change contains polyethylene glycol dimethacrylate (PEGDMA) in its composition, which might enhance its tolerance of wet conditions. Transbond Plus color change adhesive contains <2% in weight of bisphenol A diglycidyl ether dimethacrylate (bis-GMA) contrary to most of the traditional adhesives, e.g. Transbond XT that contains 10%-20%. Addition of PEGDMA might favor the infiltration of bis-GMA-based adhesives into the wet enamel.

Some contrasting findings have been observed between the present study and the studies done by Zeppieri et al.,[10] Rajagopal et al.,[11] One possible explanation for this variation may be the differences in the methodology.

Findings of this study are quite comparable to the study done by Vicente et al.,[12] on SEP and MIPs. They concluded that under contaminated condition, SEP and MIP primer should be used in conjunction with hydrophilic adhesive system rather than hydrophobic system. In another study, Santos et al.,[13] found that bond strength of SEP was not affected by contaminants such as water, saliva and blood when it was used in conjunction with a hydrophilic adhesive. Similar results have been seen in the present study.

Clinically, bond failure location of debonded orthodontic brackets is also important. The bond failure sites can be measured using scales such as the ARI, which quantifies the amount of resin remaining on the tooth after debonding.

Adhesive remnant index scores have shown significant difference among different groups. MIP dry samples have produced highest frequency of failure at enamel adhesive interface and adhesive failure. SEP under dry condition produced highest frequency of failure at bracket-adhesive interface, confirming adequate micro-mechanical retention was possible between SEP and enamel surface. MIP contaminated group have produced mainly adhesive failure and failure at enamel-adhesive interface. Self-etching contaminated produced mainly adhesive failure, which is acceptable clinically. Score 0 was least frequently observed among all the samples which further confirms that both MIP and SEP were not affected by saliva contamination and did not allow the resin-tags to be blocked by saliva. The ARI scores showed the absence of enamel fracture for all groups, which means that even the highest bond strength values were not sufficient to damage the enamel surface.

No standardized protocols exist for bond strength testing in orthodontics.[14] This makes it difficult to draw meaningful conclusions by comparing one study to another. That is one of the potential limitations of this study.

It can be concluded from the findings of the present study that in clinical situations where there is risk of contamination...
from saliva, both the MIP and SEP in conjunction with a hydrophilic adhesive can be equally effective. Standardization of laboratory (in vitro) testing in biomaterials remains a problem. Another potential limitation of in vitro model is the difficulty in reproducing the clinical oral environment. Future efforts may be directed at confirmation of the present results by in vivo studies.

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