Orthodontic bond strength with the use of non-aerosol producing bonding primers in lieu of conventional primers: An in vitro evaluation

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Abstract:

OBJECTIVE: To evaluate the efficacy of non-aerosol producing restorative self-etching primers (SEPs) as a substitute for conventional orthodontic bonding primers and to analyze the extent of residual composite on the tooth post-debonding.

MATERIALS AND METHODS: Eighty-four extracted human premolars were randomly divided into seven groups based on the adhesive and the bonding protocol used. The study comprised Prime and Bond one select (Dentsply), G-Premio Bond (GC), which were each divided into three subgroups based on the method used for moisture control and the control group (Transbond XT conventional total etch). The three methods for moisture control in study groups were: without drying, air-drying with the use of a three-way syringe, and with the use of blotting paper. Shear bond strength (SBS) was tested using a universal testing machine (UTM), and after debonding, the enamel surface of each tooth was examined under 10× magnification to evaluate adhesive remaining index (ARI) scores.

RESULTS: Groups 2A (Prime and Bond; without drying) & 1 (Transbond XT) had the lowest and highest SBS values, respectively ($P = 0.001$). Comparison of ARI between the control group and group 2b (Prime and Bond; air-drying with 3 in 1) showed a significant difference ($P = 0.041$). Comparison of ARI between control group and group 2c (Prime and Bond; blotting paper) showed a significant difference ($P = 0.017$). Rest all other comparisons were non-significant.

CONCLUSIONS: Transbond XT had SBS values higher than the self-etch groups. Among the self-etch groups, G-Premio Bond had higher SBS values when the traditional methods of air-drying were followed. Use of blotting paper for drying that produced variable SBS values can be an effective alternative method. G-Premio Bond with its adequate bond strength under manufacturer’s instruction seems promising in this regard.

Keywords: Aerosol, COVID-19, orthodontic bonding, self-etching primers

Introduction

An ideal adhesive system that bonds the bracket to enamel must be strong enough to resist all masticatory and orthodontic forces and remain adhered to the tooth and bracket throughout the course of treatment.\textsuperscript{[1]} Also, post-treatment, the orthodontist needs to remove the adhesive with minimum damage to the enamel.

An aerosol is defined as a suspension system of solid or liquid particles in a gas.\textsuperscript{[2]} The term was introduced by Frederick G. Donnan to describe an aero-solution-cloud of microscopic particles in air. The various types of aerosol, classified according to...
physical form and how they were generated, include dust, fume, mist, smoke, and fog.\textsuperscript{[3]}

According to the British Orthodontic Society, aerosol generating procedures (AGPs) are defined as any medical and patient care procedure that results in the production of airborne particles (aerosols).\textsuperscript{[4]} Both bonding and debonding procedures in orthodontics often produce aerosols, splatter, and dust.\textsuperscript{[5]}

With the advent of the current COVID-19 pandemic, these aerosols are a major concern for the spread of infection, that is, these aerosols are highly relevant to COVID-19 transmission since this may occur via both direct airborne infection and indirect spread via contact with contaminated surfaces. In August 2020, the World Health Organization (WHO) guidance regarding COVID-19 transmission opened with a discussion of AGPs and the unique infection risk faced by dental providers. They have recommended restriction of AGPs as an important control measure in COVID transmission.

As an orthodontist, both bonding and debonding a patient are probably the only AGPs and thus if we can prevent aerosols in these two procedures it may not only reduce the chances of infection transmission but may also lead to a more hygienic clinical area. Conventional acid etch bonding protocols are AGP when using polishing/pumice prior to etching and also when using three in one air syringe to rinse the teeth after etching. Non-AGP options, such as light cured resin modified GIC (Glass Ionomer Cement) and self-etching primers (SEPs), have been used as alternatives to conventional bonding protocols.\textsuperscript{[4]} Self-etching adhesive materials have been introduced recently in orthodontics to simplify the bonding process by reducing the bonding steps and eliminating the need for etching and priming, thus not only lessening the risk of contamination and reducing the bonding time,\textsuperscript{[6]} but also eliminating the use of a three-way syringe and decrease the use of suction during orthodontic bonding.

Bishara et al.\textsuperscript{[7]} evaluated the effectiveness of a self-etch primer/adhesive on the shear bond strength (SBS) of orthodontic brackets and concluded that self-etch primer, which contains both the enamel etchant and primer, has the potential to successfully bond orthodontic brackets.

Although a number of studies have been performed on these SEPs used for orthodontic bonding, there are varied results with many studies showing inadequate bond strength. Unlike orthodontic brackets, these SEPs are manufactured to retain the restoration for the entire life of the teeth. Thus the question whether these adhesives can be used for orthodontic bonding arises. A thorough review of the literature revealed that there are few studies on the orthodontic use of recently introduced SEPs manufactured for restorative dentistry.

Therefore the purpose of the present study was to evaluate the efficacy of restorative SEPs for orthodontic bonding and to analyze the extent of residual composite on the tooth post-debonding.

**Aim and Objectives**

The aim of this study was to evaluate the efficacy of restorative SEPs as a substitute for orthodontic bonding and to analyze the extent of residual composite on the tooth post-debonding.

**Objectives**

1. To evaluate and compare the bond strength of two non-aerosol producing restorative bonding primers with a conventional orthodontic primer when used according to the manufacturer’s instructions.
2. To evaluate and compare the bond strength of two non-aerosol producing restorative primers when bonded:
   - Without drying
   - Air-drying with the use of a three-way syringe
   - Drying with the help of blotting paper.
3. To evaluate and compare the ARI scores of all the different groups.

**Materials and Methods**

The current study was designed to evaluate three bonding agents using seven groups of twelve teeth each. The quantitative response variables were enamel SBS and adhesive remnant index (ARI). Ethical approval was obtained on 24/11/2020.

Eighty-four extracted human premolars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents (e.g., hydrogen peroxide), no cracks caused by the presence of the extraction forceps, and no caries. The teeth were cleaned and polished with pumice and rubber prophylactic cups for 10 s. Teeth were randomly divided into seven groups, based on the adhesive to be used and the protocol applied: G-Premio Bond (GC), Prime and Bond one select (Dentsply), which were each divided further into three subgroups based on the method used for moisture control, and the control which was Transbond XT conventional total etch. The three groups in self-etch groups were: without the use of a three-way syringe, with the use of a three-way syringe, and with the use of blotting paper.

To bond the stainless steel premolar brackets, Transbond XT Light Cure Adhesive (3M Unitek) was compressed...
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with a plastic instrument into the mesh of the brackets, which were then placed on the buccal surface of the tooth, with their slots parallel to the incisal edge. After pressing the brackets onto the buccal surfaces of the teeth with a carver instrument and gentle removal of any excess adhesive, the curing light was held stationary at a distance of 1–2 mm from the bracket for 12 s, with the light beam directed for 6 s each at the mesial and distal aspects of the bracket.

Standard protocol for G-Premio Bond and Prime and Bond was that we left it undisturbed for 10 s after application, dried it for 5 s, and light cured for 10 s. Application time was 30 s from application time to light cure. This was further modified according to our subgroups.

To test the SBS, each sample was mounted on the universal testing machine (UTM) such that the facial surface of the tooth was parallel to the chisel so that it contacted each bracket from the incisal aspect as close to the bonding interface as possible. Each bracket was then debonded at a crosshead speed of 1 mm/min. The maximum force required to debond a bracket was recorded and mean SBS (in MPa) was calculated for each group.

After debonding, the enamel surface of each tooth was examined under 10 × magnification and classified according to the ARI scores described by Artun and Bergland, where 0 = no adhesive left on tooth, 1 = <50% left on the tooth surface, 2 = >50% left on the tooth surface, and 3 = all adhesive left on the tooth surface. The frequency of each score was noted and compared among groups.

Statistical analysis
The data was collected, compiled, tabulated, and subjected to statistical analysis. The descriptive statistics, including the means, standard deviations, minimum, and maximum values, was calculated for each group. SPSS 20 was used in the calculation of all statistics and the level of significance was kept at 5%.

Independent t-test and Mann–Whitney U test for intergroup comparisons were applied.

Results

SBS
Table 1 shows SBS of various groups and subgroups with mean ± SD along with the maximum and minimum values. Groups 2A and 1 had the lowest and highest SBS values, respectively ($P = 0.001$). The results of SBS among various groups showed that

Gp1>Gp 3B>Gp 3A>Gp 2C>Gp 3C>Gp 2B>Gp 2A.

Table 2 shows inter- and intra-group comparison of SBS and their $P$ values.

ARI
Table 3 shows ARI of various groups and subgroups with mean ± SD.

Group 1 had the highest mean score and Groups 2a and 2c had the lowest.

The results of ARI among various groups showed that Gp1>Gp 3A>Gp 3B = Gp 3C>Gp 2B>Gp 2A = Gp 2C.

Table 4 shows inter- and intragroup comparison of ARI and their $P$ values.

| Groups | Mean | SD  | Maximum | Minimum |
|--------|------|-----|---------|---------|
| Group 1 | 14.79 | 3.29 | 208.88  | 98.07   |
| Group 2A | 7.10  | 1.51 | 111.8   | 46.09   |
| Group 2B | 9.21  | 1.45 | 114.75  | 80.41   |
| Group 2C | 10.93 | 4.57 | 220.65  | 51.98   |
| Group 3A | 11.15 | 3.83 | 208.88  | 82.38   |
| Group 3B | 12.56 | 2.75 | 176.52  | 89.24   |
| Group 3C | 10.82 | 3.96 | 228.49  | 65.7    |

Table 2: Inter- and intra-group comparison for SBS

| Group Comparison | $P$ | Significance |
|------------------|-----|--------------|
| G1 vs 2A         | 0.001 | Sig        |
| G1 vs 2B         | 0.001 | Sig        |
| G1 vs 2C         | 0.027 | Sig        |
| G1 vs 3A         | 0.021 | Sig        |
| G1 vs 3B         | 0.087 | NS         |
| G1 vs 3C         | 0.014 | Sig        |
| 2A vs 2B         | 0.193 | NS         |
| 2A vs 2C         | 0.008 | Sig        |
| 2A vs 3A         | 0.004 | Sig        |
| 2B vs 2C         | 0.327 | NS         |
| 2B vs 3B         | 0.002 | Sig        |
| 2C vs 3C         | 0.954 | NS         |
| 3A vs 3B         | 0.598 | NS         |
| 3A vs 3C         | 0.972 | NS         |
| 3B vs 3C         | 0.462 | NS         |

Independent t-test, $P \leq 0.05$; NS: Non-significant; Sig: Significant

Table 3: ARI of various groups and subgroups with mean

| Groups | Score 0 | Score 1 | Score 2 | Score 3 | Mean |
|--------|---------|---------|---------|---------|------|
| Group 1 | 0       | 2       | 4       | 6       | 2.33 |
| Group 2A| 4       | 2       | 3       | 3       | 1.42 |
| Group 2B| 0       | 8       | 1       | 3       | 1.58 |
| Group 2C| 1       | 7       | 2       | 2       | 1.42 |
| Group 3A| 0       | 3       | 3       | 6       | 2.25 |
| Group 3B| 0       | 2       | 7       | 3       | 2.08 |
| Group 3C| 0       | 4       | 3       | 5       | 2.08 |
Table 4: Inter- and intra-group comparison of P values for ARI

| Group Comparison | P     | Significance |
|------------------|-------|--------------|
| G1 vs 2A         | 0.061 | NS           |
| G1 vs 2B         | 0.041 | Sig          |
| G1 vs 2C         | 0.017 | Sig          |
| G1 vs 3A         | 0.850 | NS           |
| G1 vs 3B         | 0.347 | NS           |
| G1 vs 3C         | 0.495 | NS           |
| 2A vs 2B         | 0.671 | NS           |
| 2A vs 2C         | 0.952 | NS           |
| 2A vs 3A         | 0.086 | NS           |
| 2B vs 2C         | 0.688 | NS           |
| 2B vs 3B         | 0.096 | NS           |
| 2C vs 3C         | 0.083 | NS           |
| 3A vs 3B         | 0.515 | NS           |
| 3A vs 3C         | 0.641 | NS           |
| 3B vs 3C         | 0.951 | NS           |

Mann–Whitney U test. P ≤ 0.05; NS: Non-significant; Sig: Significant

Discussion

The introduction of direct bonding of orthodontic brackets revolutionized and improved the clinical practice of orthodontic procedures and improvements continue through the introduction of new materials. The entry of seventh and eighth generation of bonding agents has simplified the bonding procedure, reducing chair time and minimizing enamel loss.

Self-etch primers combine etching and priming in a single stage. The reactive components are esters from bivalent alcohols with methacrylic and phosphoric acid or its derivatives. The phosphate residue is to etch the enamel, whereas the methacrylate component of the molecule is available for copolymerization with the bonding agent and composite resin.[8] Prati et al.[9] who studied bond strength of self-etch primers in dentin, reported that they are superior to conventional primers despite their limited resin-infiltrated dentin layer thickness. Other studies using self-etch primers on enamel showed that they offered clinically adequate bond strength but are inferior to conventional primers.[7,10] The elimination of washing and drying of tooth minimizes the probability of contamination and reduces aerosol generation, which is a much needed requirement in this COVID era.

WHO, in its guidance dated August 3, 2020, opens with a discussion of COVID-19 transmission, AGPs, and the unique infection risk faced by dental providers. Evidently, common categories and burdens of orthodontics-related applications producing aerosol and/or airborne particulates focus on bonding and debonding strategies. The former involves application of water-spray practices in connection to enamel etching, before conditioning with bonding agents and bracket bonding; the latter pertains to enamel clean-up practices after removal of fixed appliances on completion of orthodontic treatment.[8]

SEP alternatives have been proposed to avoid rinsing application and aerosol production. Restriction of AGPs is, therefore, an important control measure. Though some studies have been conducted to compare the bond strength of self-etch primers, its potential use as a non-AGP substitute is the call of the hour.

This study was thus performed by comparing three bonding systems, a conventional system using etching, priming and adhesive placement and two self-etch systems, one seventh generation and one eighth generation, using three different methods of moisture control. The various methods used for moisture control included: without the use of a three-way syringe for drying, with the use of a three-way syringe, and with the use of blotting paper. The SBS values were tested using UTM and compared with other groups and subgroups. In this study, mean SBS of Transbond XT was 14.79 MPa, which was the highest among all groups and correlates with other studies.

The least value of the SBS of SEP (Prime&B Bond one select) was found for the group without drying to be 7.10 ± 1.51 MPa, which was less compared to conventional acid etching (Transbond XT). The eighth generation G-Premio Bond showed better SBS values, which ranged from 10.82 ± 3.96 for the blotting paper group to 12.56 ± 2.75 for the air-drying group. The findings indicated that the use of an SEP to bond orthodontic brackets to the enamel surface provided lower, but clinically acceptable, shear bond forces.[11] Results in the present study are similar to those obtained in the study performed by Bishara et al.[7] in which the use of SEP resulted in a significantly lower but clinically acceptable shear bond force (7.1 ± 4.4 MPa).

The use of blotting paper with both the SEPs showed greater variability in SBS values, for Prime and Bond one -select 220.65 and 51.98 maximum and minimum values, respectively, with a mean of 10.93 and SD of 4.57; and for G-Premio Bond 228.49 and 65.7 maximum and minimum, respectively, with a mean of 10.82 and SD of 3.96, which can be an indication of different pressure applied with the blotting paper. Thus, it can be technique sensitive and not very reliable.

The manufacturer’s recommendations for the G-Premio SEP used in the present study called for 5 s of air-drying. When air dispersion was correctly accomplished, the mean bond strength of this primer system was found to be closer to the conventional, multistep bonding procedure. Comparison of SBS between Transbond XT and G-Premio Bond with air-drying showed no
significant difference in SBS (P = 0.087), though the comparison of SBS within group 3 showed no significant difference between the groups without air-drying, with air-drying, and with the use of blotting paper.

The ARI is one of the most commonly used methods of assessing the quality of adhesion between the composite and tooth, as well as between the composite and bracket base. This relation was apparent when we looked at bond strength and the amount of resin remaining after debonding in the control group and the self-etch group. These results are in agreement with Sharma et al., who showed that a total-etch system had a greater ARI score than self-etch systems. In addition, Schnebel et al. showed that total-etch adhesives fail mainly at the bracket-adhesive interface, thus leaving more residual resin on the enamel surface. This could be clinically advantageous because when brackets fail at the enamel-adhesive interface, less adhesive remains and tooth clean-up is likely to be easier and faster.

As bracket failure occurs at the weakest interface, this also indicates a weaker bond to the enamel surface, resulting in lower SBS. Here in this study, the Prime and Bond one-select showed least SBS values among the three groups and the mean values of ARI were also the lowest in this group. In fact comparison of ARI between control group and groups 2b (P = 0.041) and 2C (P = 0.017) showed significant difference.

Here in this study, comparison of ARI of Transbond XT group had no significance with Prime and Bond group without air-drying and with the use of blotting paper and with all the three groups of G-Premio Bond. This is in contrast to the study by Meerbeek et al., who experimented with one etch-and-rinse type and one self-etch type adhesive and concluded from their ARI scores that different magnitudes of bonding force had significantly different failure modes in each adhesive group.

**Drawbacks of this study**

The present study is an *in vitro* study, and results of this study can vary when extrapolated to the intraoral environment. So, further long-term clinical studies simulating intra-oral conditions or *in vivo* studies are needed to be carried out before actually recommending the use of SEP in routine orthodontic bonding. Time is another factor which has not been considered in this study but cannot be ignored. Also, every manufacturer has a recommended protocol to be followed with its use and any variation is bound to vary the SBS values. Hence there is a need for further study simulating intra-oral conditions and time frame.

**Conclusion**

In this *in vitro* study, we found that:

- Transbond XT had SBS values higher than the self-etch groups, though the self-etch groups also had SBS higher than the range of 5.9–7.8 MPa considered by Reynolds to be adequate for routine clinical use.
- Among the self-etch groups, G-Premio Bond had higher SBS values when the traditional methods of air-drying were followed.
- Use of blotting paper for drying, though produced variable SBS values, can be an effective alternative method.
- Measures to control the generation of aerosol in orthodontic practice should be practiced. Minimization of water-spray syringe utilization for rinsing can be achieved with the use of self-etch primers. G-Premio Bond with its adequate bond strength under the manufacturer’s instruction seems promising in this regard.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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