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Effect of different times of solvent evaporation and pH in two self-etching adhesive systems on the shear bond strength of metallic orthodontic brackets

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ABSTRACT

Objectives: The aim of this study was to evaluate the shear bond strength (SBS) of metal brackets bonded with two self-etching adhesives using different times of air drying.
Materials and methods: 120 healthy bovine incisors were divided into 6 groups ($n=20$). Transbond Plus Self Etching Primer and Adper Easy One Self-Etch Adhesive were gently dried at a distance of 20 cm for 3 different times (5 s, 10 s and 15 s). Metal incisor orthodontic brackets were used. The pH of the adhesives was tested with indicator strips and the specimens were tested using a universal testing machine (Instron 3342). Once debonded, each specimen was examined to identify the failure mode (ARI) and SEM was utilized to visualize the enamel conditions. SBS data were subjected to Two-way ANOVA and Tukey tests, while ARI data were analyzed using the Kruskal–Wallis test ($p=0.05$).
Results: Statistically significant differences were found between Groups Transbond 5 (11.72 ± 1.52), Transbond 10 (15.25 ± 2.27) and Transbond 15 (20.45 ± 1.93), with increases in SBS values as exposure time to the air jet was increased. For adhesive Easy One, there was no statistically significant difference between Groups Easy One 5 (13.10 ± 3.46) and Easy One 10 (16.43 ± 2.56), or between Groups Easy One 10 and Easy One 15 (18.43 ± 2.46). There were no differences between ARI values in the tested groups.
Conclusions: The SBS of the self etching adhesive was directly influenced by the length of time air drying was applied. The pH did not affect the shear bond strength and SEM showed conserved enamel after debonding, suggesting that a smaller amount of adhesive on the enamel surface is better.

1. Introduction

Conventional (etch-and-rinse) adhesive systems are technique sensitive, due to the excessive number of steps that may lead to operator error [1]. For this reason, self-etching systems have been widely used because of the shorter application time and reduced number of steps [2,3]. Self-etching systems providing a simpler and faster technique that is, therefore, less sensitive to operative errors [4], consequently minimizing the time of clinical attendance [5,6].

Besides these advantages, it has been demonstrated that the shear bond strength values of brackets bonded with self-etching primers are not significantly different from brackets bonded with the conventional acid-etch technique [7,8].

Simplified self-etching adhesives combine acidic monomers and solvents in a single bottle [9,10]. Their bond is based on the infiltration of acid resin monomers [11] that demineralize the enamel and simultaneously penetrate into its hydroxyapatite crystals [5].

Solvents are not only important but indispensible components in the composition of adhesive systems, and water and ethanol are the most commonly used solvents. Their function in self-etching adhesives is to guarantee ionization of the acidic monomers, thereby providing the capacity to demineralize the enamel substrate [12,13], and the presence of water is necessary to trigger the

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demineralization process [14]. However, during the bonding process, the application of an air jet is indispensible to facilitate removal of the solvent present in the adhesive layer before light activation [10].

Therefore, there is concern about the effect of residual solvent within the adhesive interface [15,16]. The time of application of the air jet recommended by the manufacturer has not been shown to be well defined, and choosing the length of time to apply the air jet is left to the operator's discretion. Thus, incomplete solvent evaporation occurs when the air jet is applied for too short a time [17], resulting in reduced bond strength in these adhesives [18,19].

On the other hand, applying the air jet for too long may incorporate oxygen and thus interfere with polymerization due to inhibition, or even favor the appearance of air bubbles [20,21].

Thus, the aim of this study was to evaluate the shear bond strengths of metal brackets bonded with two self-etching adhesives, evaluating different times of air jet application, and determine whether the pH of the adhesive affects the SBS and the enamel conditions after debonding using scanning electron microscopy (SEM).

2. Experimental

2.1. Materials and methods

A total of 120 healthy bovine incisors without obvious enamel defects were selected. To control bacterial growth, they were stored for 2–3 months in 0.1% thymol, which was changed periodically to avoid deterioration.

The teeth were embedded in PVC tubes in acrylic resin, with only the coronal part remaining visible. Next, the vestibular surfaces were treated with pumice stone and a rubber cup for 10 seconds, afterwards being washed and dried. One hundred and twenty Standard Edgewise (3 M Unitek, Monrovia, California, USA) metal incisor orthodontic brackets were used. The base area of each bracket was calculated (mean=12.06 mm^2) using a digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, Japan).

Two adhesive systems, Transbond Plus Self Etching Primer (3 M Unitek Monrovia, USA) and Adper Easy One Self Etch Adhesive (3 M ESPE, St. Paul, USA), were used. The 120 bovine teeth were divided into 6 groups (n=20): Transbond 5, Transbond 10 and Transbond 15. Easy One the groups: Easy One 5, Easy One 10 and Easy One 15. All the conditions were dried at a distance of 20 cm with a pressure of 2 bar. The material compositions and application modes are described in Table 1.

Transbond XT resin (3M Unitek, Monrovia, USA) was applied at the base of the bracket for all groups, which was placed on the vestibular surface of the tooth using a tensiometer (Odeme Biotechnology, Joaçaba, Brazil) with a force of 300 g for 10 s [6] to ensure a uniform resin thickness. Light activation was performed with an Optilux 501 unit (600 mw/cm^2 Kerr, Orange, USA) on two faces (mesial and distal) for 20 s on each proximal face. The test specimens were kept in water at 37 °C for 24 h.

2.2. Shear bond strength

The shear bond strength test was performed on a universal test machine (Instron 3342, Canton, Massachusetts, USA), applying an ocluso-gingival load at a speed of 0.5 mm/min. using a chisel applied on the bracket/enamel interface. The force required to debond each bracket was recorded in Newtons (N) and converted into Mega-Pascals as a ratio of Newtons to surface area of the bracket (MPa=N/mm^2).

2.3. Failure mode evaluation (ARI)

After bond strength testing, all specimens were visually examined with a stereomicroscope (Kozo Optical and Electronic Instrumental, Nanjing, China) at 10× magnification to assess the fracture pattern and adhesive remnant index (ARI): score 0, no composite resin left on the tooth; score 1, less than half of the composite resin left on the tooth; score 2, more than half of the composite resin left on the tooth; and score 3, all of the composite resin left on the tooth, with a distinct impression of the bracket mesh. Scanning electronic microscopy (Hitachi, TM3000, Japan) was used to evaluate the enamel condition in 2 specimens with each adhesive according to the different fracture patterns found after bracket debonding.

2.4. Measurement of pH

The pH of each adhesive was evaluated with a pH indicator strip, with a range of 0–7 (Merck, Darmstadt, Germany) to determine the most accurate paper for each adhesive. Thus, the initial evaluation showed that for both adhesives, the indicated indicator strips should have a range of 0–2.5. Then, the adhesives were scattered on the surface of the indicator strips. After 40 s, an analysis was made comparing the color obtained in the strips and the color scale of the pH system. This step was repeated 3 times for each adhesive.

2.5. Statistical analysis

The bond strength data were submitted to Analysis of Variance (ANOVA for 2 factors) (Adhesive vs. Time of air jet) and Tukey's test for contrast between means (α=0.05).

Table 1
Materials used in the present study and the modes of application*.

Adhesive	Composition	Application mode
Transbond Plus Self Etching Primer 3M Unitek, Monrovia, USA (471423)	Methacrylate ester derivative, Water	1 Vigorous application of primer/adhesive (5 s) 2 Drying at a distance of 20 cm 3 Light polymerization (10 s), 4 Application of resin on bracket base 5 Light activation (40 s)
Adper Easy One Self-Etch Adhesive 3M ESPE, St. Paul, USA (457656)	2-Hydroxyethyl methacryate (HEMA), Bis-GMA Methacrylated phosphoric esters, 1,6 hexanediol dimethacrylate, Methacrylate functionalized, Polyalkenoic acid (Vitrebond™ Copolymer), Silica filler with 7 nm primary particle size, Ethanol and Water, Initiators based on camphorquinone, Stabilizers	1 Vigorous application of primer/adhesive (20 s) 2 Drying at a distance of 20 cm 3 Light polymerization (10 s), 4 Application of resin on bracket base 5 Light activation (40 s)

* Composition of material according to information obtained from the respective manufacturers.