Original Article

Shear Bond Strength of Metallic Orthodontic Brackets Bonded to Enamel Prepared with Self-Etching Primer

Fábio Lourenço Romano[a]; Stenyo Wanderley Tavares[b]; Darcy Flávio Nouer[c]; Simonides Consani[d]; Maria Beatriz Borges de Araújo Magnani[e]

Abstract: The aim of this study was to determine the shear bond strength of different composites and to determine the adhesive remnant index (ARI) of metallic brackets bonded to enamel prepared with Transbond Plus Self-Etching Primer (TPSEP). Forty human premolars were divided into four equal groups. In group 1 (control), the Transbond XT was conventionally used. In groups 2–4, the TPSEP was used before bonding with Transbond XT, Z-100, and Concise Orthodontic, respectively. After the bonding, the samples were stored in distilled water at 37°C for 24 hours. The brackets were debonded using a universal testing machine at a crosshead speed of 0.5 mm/min. The shear bond strength (MPa) for group 1 (control), group 2 (TPSEP + Transbond XT), group 3 (TPSEP + Z-100), and group 4 (TPSEP + Concise Orthodontic) were of 6.43, 4.61, 4.74, and 0.02, respectively. Group 1 was statistically superior to other groups ($P < .05$), but there was no statistically significant difference between groups 2 and 3 ($P > .05$), although both were statistically superior to group 4 ($P < .05$). According to the ARI evaluation, most of the failures involved the bracket/composite interface (groups 1 and 2) as well as the enamel/composite interface (groups 3 and 4). The Transbond XT conventionally bonded showed better adhesion results than Transbond XT, Z-100, and Concise Orthodontic after using Transbond Plus Self-Etching Primer. (*Angle Orthod* 2005;75:849–853.)

Key Words: Shear bond strength; Orthodontic brackets

INTRODUCTION

The conventional bonding of orthodontic materials to enamel surfaces has produced good adhesive results. However, it is time consuming because a series of steps has to be followed for its execution, namely, acid etching, primer application, and the bonding itself.[1–7]

To simplify the procedure and to reduce the time spent for orthodontic bonding, self-etching primer (SEP) products are available in the dental market, which use a mixture combining acid and primer into one solution. According to White,[8] SEPs are easily manipulated and used, resulting in comfort for the patients and decreasing the chair time by 65%.

Transbond Plus Self-Etching Primer (TPSEP, 3M Unitek, Monrovia, Calif) is a sixth generation adhesive composite developed for orthodontic bonding whose chemical formulation is similar to that of phosphoric acid, although its solid matrix is formed by two chains. The same monomer that causes acid etching also allows primer penetration. This results in a selective preparation of the enamel with placement of the primer into the demineralized region at the same time.[9,10] In addition, the penetration involves the entire area of the previously etched enamel without requiring the traditional washing after acid application.[10–12]

TPSEP has been studied and, according to several laboratory tests, the agent used before the bonding of brackets showed promising adhesive results.[13,14]

[a] Master of Orthodontics, Piracicaba Dental School—UNICAMP, São Paulo, Brazil.
[b] Doctor of Orthodontics, Piracicaba Dental School—UNICAMP, São Paulo, Brazil.
[c] Full Professor of Orthodontics, Department of Child Dentistry, Piracicaba Dental School—UNICAMP, São Paulo, Brazil.
[d] Full Professor of Dental Materials, Department of Restorative Dentistry, Piracicaba Dental School—UNICAMP, São Paulo, Brazil.
[e] Doctor and Professor of Orthodontics, Department of Child Dentistry, Piracicaba Dental School—UNICAMP, São Paulo, Brazil.
Corresponding author: Fábio Lourenço Romano, M Orth, Piracicaba Dental School—UNICAMP, Avenida do Café, 131 Bloco E-Apto 16 Vila Amélia, Ribeirão Preto, São Paulo, Brazil 14050-230
(e-mail: flromano@aol.com)

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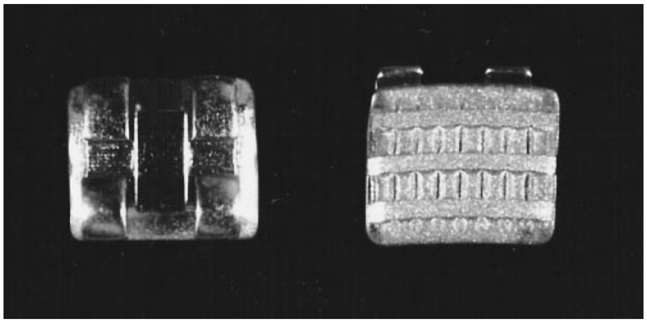

FIGURE 1. Bracket Mini Dyna-Lock Standard.

These results were, in fact, superior to those showed by conventional bonding in either humid or dry environments, including the contamination by saliva.[10–12,15–18]

In most of the studies on TPSEP, the brackets were bonded using the Transbond XT composite according to the manufacturer's recommendations. However, orthodontists generally use a large number of materials for bonding orthodontic materials including other composites, compomers, and glass ionomer cements.[19]

The aim of this study was to verify the shear bond strength and the adhesive remnant index (ARI) of metallic brackets bonded with different composites to enamel that had been prepared with TPSEP.

MATERIALS AND METHODS

Forty healthy human extracted maxillary and mandibular premolars were used. All teeth were newly extracted for orthodontic reasons and presented no caries, cracks, or fissures. Their buccal surfaces were intact, and they had not been subjected to any kind of orthodontic or endodontic treatment. The study protocol was authorized by the Faculty of Dentistry of the Piracicaba Research Ethics Board.

After extraction, the teeth were cleaned using periodontal curettes and stored in a solution of 0.1% (wt/vol) thymol at a temperature of approximately 4°C. Next, the roots of these teeth were placed centrally into PVC tubes containing self-polymerizing acrylic resin at a sandy phase but avoiding contact between resin and crown. The excess resin was removed using a sharp scaler, and the teeth were stored in distilled water at room temperature.

The buccal surfaces of all teeth were cleaned using nonfluoridated pumice and water for 10 seconds. The teeth were also polished using a rubber cup, abundantly washed, and dried using an air syringe free of oil and humidity. Forty Mini Dyna-Lock Standard Edgewise metallic brackets for premolars (3M Unitek) without angulation or torque were used. The brackets presented a base area of 9.40 mm^2 (Figure 1).

To evaluate the materials to be used, the samples were divided randomly into four groups ($n = 10$), and the representative number of samples for each group was determined according to previous statistical analysis as follows:

- Group 1 (control): The enamel surface was etched with 35% phosphoric acid (3M Dental Products, Monrovia, Calif) for 30 seconds, washed for 20 seconds, and dried for the same period of time. Transbond XT primer was applied on the etched surfaces, and the brackets were bonded by using only Transbond XT composite (3M Unitek).
- Group 2: TPSEP was applied and rubbed on the enamel surfaces for approximately three seconds. An air jet was slightly applied to the enamel, and the brackets were bonded with Transbond XT.
- Group 3: TPSEP was applied and rubbed on the enamel surfaces for approximately three seconds. Air jet was slightly applied to the enamel, and the brackets were bonded with Z-100 (3M, St Paul, Minn).
- Group 4: TPSEP was applied and rubbed on the enamel surfaces for approximately three seconds. Air jet was slightly applied to the enamel, and the brackets were bonded with Concise Orthodontic (3M Dental Products).

All bonding procedures were performed by the same operator. The excess bonding material was removed with a scraper. The samples from groups 1–3 were light cured for 40 seconds (10 seconds for each face—mesial, distal, incisive border, and gingival) with an XL 1500 light (3M Unitek, Sumaré, Brazil) with an intensity of 550 mW/cm^2. The light unit tip was one mm from each bracket face, and its intensity was calibrated for each polymerization using a radiometer (Demetron, Danbury, Conn). The bonding procedures using the Concise Orthodontic composite (group 4) took place by chemical activation.

After the bonding procedures, the samples were stored in distilled water at 37°C for 24 hours. The brackets were debonded using a universal testing machine (Instron Corp., Canton, Mass) at a crosshead speed of 0.5 mm/min. The samples were fixed to the testing machine by wire rings (0.019- $\times$ 0.025-inch) attached to the bracket slot and to the machine's clamps (Figure 2). In this test, however, the resulting stress in the tooth-bracket bonding zone represented the shear bond strength. The rings were replaced with new ones for every 10 traction tests. The shear bond strength values were obtained in kilogram forces and were divided by the bracket's area to convert them into megapascals.

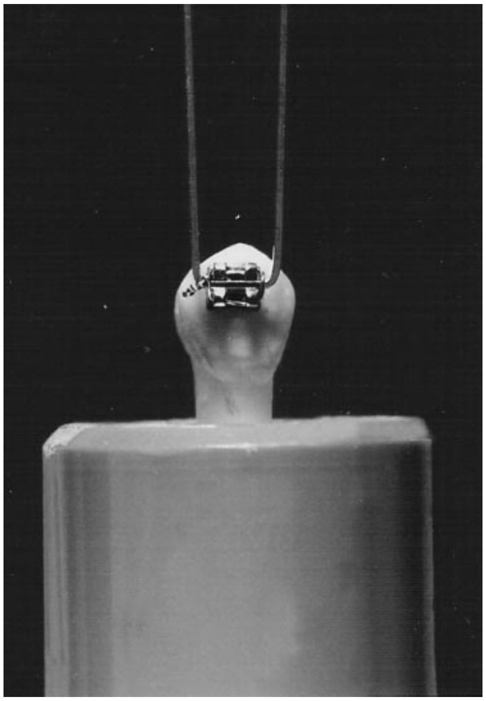

FIGURE 2. Shear test using the Instron machine.

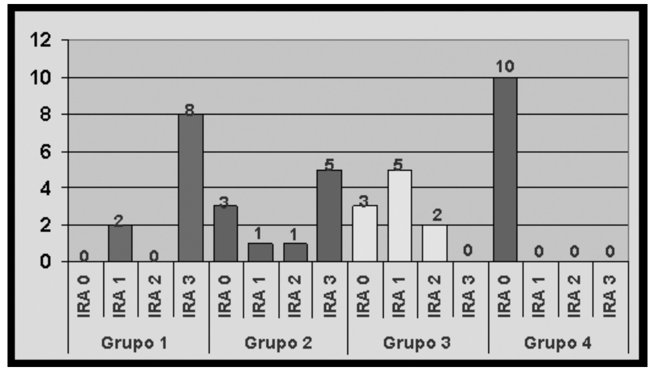

FIGURE 3. Adhesive remnant index (ARI) values within each group.

The ARI for each group was estimated after the debonding procedures using a stereoscopic magnifying glass (Carl Zeiss, Göttingen, Germany) with eight times magnification. These indexes were recorded using the ARI scores established by Årtun and Bergland,[20] ie, 0 = no adhesive remaining, 1 = less than half of the adhesive remaining, 2 = more than half of the adhesive remaining, and 3 = all adhesive remnant.

The results of the shear bond strength were submitted to analysis of variance and Tukey tests (5% significance) in order to compare the mean values among the groups. The ARI scores were evaluated by using the Kruskal-Wallis test.

RESULTS

The shear bond strength values and the Tukey tests for all the groups are shown in Table 1. Statistically significant differences were found among the groups ($P > .0001$).

Group 1 (control) was statistically superior to the other groups ($P < .05$). On the other hand, there was no statistically significant difference between group 2 (TPSEP + Transbond XT) and group 3 (TPSEP + Z-100) ($P > .05$), although both these groups were statistically superior to group 4 (TPSEP + Concise Orthodontic).

The ARI scores calculated for each group are presented in Figure 3. The results obtained from the Kruskal-Wallis test indicate statistically significant differences among the groups. In relation to the ARI, the comparisons between groups 1 and 2, between groups 2 and 3, and between groups 3 and 4 showed no statistically significant differences: $P = .175$, $P = .235$, and $P = .069$, respectively. However, the comparison between groups 1 and 3, between groups 1 and 4, and between groups 2 and 4 did show statistically significant differences: $P = .011$, $P = .000$, and $P = .002$, respectively.

DISCUSSION

The TPSEP was developed to be used before bonding in order to reduce the steps required for fixing the orthodontic brackets as well as the chair time, thus promoting comfort to both patients and orthodontists.

According to the manufacturer, to achieve a good adhesive result, this self-etching primer should be used together with the Transbond XT composite. In addition, the use of other bonding materials is not recommended by the manufacturer. In this study, TPSEP was been used before bonding metallic brackets using

TABLE 1. Results (MPa) and Statistical Analysis (ANOVA and Tukey) of the Evaluated Groups

Groups	n	Mean	SD	Range	Tukey Test (5%)[a]
Conventional Transbond XT	10	6.43	1.87	4.38–9.82	A
TPSEP + Transbond XT[b]	10	4.61	0.87	3.19–6.07	B
TPSEP + Z-100	10	4.74	1.28	3.58–6.86	B
TPSEP + Concise Orthodontic	10	0.02	0.06	0–0.02	C

[a] Same letters indicate lack of statistically significant difference.
[b] TPSEP indicates Transbond Plus Self-Etching Primer.

other composites (Z-100 and Concise Orthodontic), whose adhesive values were different for each material used.

The mean adhesive value (6.43 MPa) estimated for group 1 (control) was similar to that found in some studies[1,4,17] but inferior to the majority of the experiments existing in the literature.[2,3,5,6,10,12,15,16]

The discrepancy involving the results was probably due to the different methodologies used by those studies, and such a fact may explain the differences observed. Despite this, the result achieved by this study is within the average range suggested by Reynolds[21] in terms of clinical (5.9–7.8 MPa) and laboratory (4.9 MPa) performances.

The shear bond strength mean value of 4.61 MPa presented in group 2 (TPSEP + Transbond XT) was statistically inferior to group 1 (control) and was believed to be low in comparison with other researches[10,12,14–18] as well. On the other hand, some studies on bonding materials showed no statistically significant differences between the control and experimental groups.[10,12,15–17]

In group 3, the shear bond strength mean value of 4.74 MPa was obtained by using TPSEP together with the Z-100 composite, thus contradicting the manufacturer's recommendations. Such a value is less than that found by Correr Sobrinho et al[4] who had used this composite after etching the enamel using 35% phosphoric acid. Despite this low value, no statistically significant difference was found in group 3 in comparison with group 2.

It was not possible to perform the shear bond strength test in the great majority of samples (90%) of group 4 (Concise Orthodontic + TPSEP) because the debonding occurred during the placement of the orthodontic wires into the bracket slots. The lack of adhesion observed in group 4 shows that TPSEP should be used only for bracket bonding with the composites specified in the manufacturer's recommendations. The poor adhesion involving the Concise Orthodontic composite and TPSEP probably is due to the weak chemical interaction between these materials. The result shows that the self-etching primer should only be used for bonding light activated materials (eg, Transbond XT) and not for chemically polymerized materials (eg, self-polymerization composites).

The poor shear bond strength observed in groups 3 and 4 suggests a chemical incompatibility involving the materials (Z-100 and Concise Orthodontic) when used together with TPSEP. This fact confirms the SEP manufacturer's statement that the effective adhesion can only be achieved by using the Transbond XT composite.

With respect to the ARI, eight samples from group 1 (Figure 3) presented adhesive failures on the bracket/composite interface (ARI values = 3, 100% adhesion to the enamel) and two samples presented mixed failures (ARI values = 1, less than 50% adhesion to the enamel). The high ARI values observed in group 1 are directly related to the mean adhesion values presented by the Transbond XT composite conventionally used. This happens because the microporosities caused by the acid etching allows further primer penetration and improved mechanical union between the composite and enamel.[1,6,10,16,18]

Five group 2 samples presented adhesive failures at the bracket/composite interface (ARI = 3), whereas three samples had no composite adhesion to the enamel (ARI = 0), thus indicating an adhesive failure. The low values for those samples were probably due to the poor substrate etching. Such results are similar to those observed by Buyukyilmaz et al[16] but different from those found by Cacciafesta et al[10] and Zeppieri et al,[18] who obtained a greater number of poor adhesions (ARI values = 0 and 1, respectively).

The lowest ARI values were observed in groups 3 and 4 (Figure 3), with no statistically significant differences between them. Group 3 had predominantly ARI values = 1, followed by ARI values = 0 and 2, and differently from the other groups, with the majority of failures being mixed. Despite presenting smaller ARI values in relation to group 2, there was no statistically significant difference between both groups. In group 4, no bracket adhesion to the enamel was observed and, as a result, all the samples had enamel adhesive failure (ARI value = 0).

CONCLUSIONS

The following conclusions can be drawn from this study:

- Transbond XT conventionally bonded to the enamel was superior to Transbond XT, Z-100, and Concise Orthodontic composites + TPSEP.
- Concise Orthodontic + TPSEP showed poor adhesion to the enamel.
- The majority of failures observed in the groups using conventional Transbond XT, Transbond XT + TPSEP, and Z-100 were mixed. The group using Concise Orthodontic + TPSEP showed adhesive failures to the enamel.

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