Original Article

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Shear bond strength of metallic brackets bonded with a new orthodontic composite

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Abstract

Aim: The aim of this study was to assess the shear bond strength of orthodontic brackets in different enamel surfaces using the Transbond Plus Color Change composite (TPCC-3M Unitek), and to analyze the Adhesive Remnant Index (ARI). **Methods:** Seventy-two human premolars were divided into six groups (n = 12), as follows: Group 1(control) - Transbond XT conventional; in Groups 2 to 6, TPCC was used under the following enamel treatment conditions: phosphoric acid and XT-primer; Transbond Plus Self-Etching Primer (TPSEP); phosphoric acid only; phosphoric acid, XT-primer and saliva; and TPSEP and saliva, respectively. Twenty-four hours after bonding, the brackets were debonded with an Instron machine at a crosshead speed of 0.5 mm/min, and ARI was evaluated by using a stereoscopic magnifying glass. **Results:** The mean shear strength values (MPa) for Groups 1 to 6 were 24.6, 18.7, 17.5, 19.7, 17.5 and 14.8, respectively. Data were submitted to ANOVA and Tukey's test ($\alpha = 0.05$). Group 1 had significantly higher shear bond strength values than Groups 3, 5, and 6 ($p < 0.05$), but did not differ significantly from Groups 2 and 4 ($p > 0.05$). No statistically significant differences ($p > 0.05$) were found between Groups 2, 3, 4, 5 and 6. **Conclusions:** Bracket bonding using TPCC showed adequate adhesion for clinical use, and the type of enamel preparation had no influence.

Keywords: composite resins, shear strength, orthodontic brackets, orthodontics.

Introduction

Composites are the most common materials used for bonding dental accessories to enamel directly because of the adequate adhesive values obtained in laboratory and clinical experiments[1-4]. In order to bond brackets using composites conventionally, the enamel surface must be properly prepared by prophylaxis and acid etching before application of the bonding agent. All these procedures are time-consuming, increase the clinical chairtime, make it more difficult to keep the operative field dry and increase the risks of bracket debonding due to salivary or moisture contamination[5,6].

In order to simplify the bonding procedures, new bonding systems combining etchant and primer in one solution have emerged – the self-etching primers (SEPs). One of these systems is Transbond Plus Self-Etching Primer (TPSEP, 3M Unitek, Orthodontic Products, Monrovia, CA, USA), an orthodontic bonding agent tested in several laboratory and clinical

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experiments as an enamel-etching agent to be used before bracket bonding procedure, with promising adhesive results[2,5,7-16].

A new adhesive composite, Transbond Plus Color Change (TPCC, 3M Unitek), has been recently developed. It is characterized as having an initial pink color, that facilitates the removal of excess material, and becoming transparent after photo-activation. According to the manufacturer, this material releases fluoride and has hydrophilic characteristics that allow its use under conditions of contamination and presence of moisture without decreasing its adhesiveness. Enamel surface preparation for use of this material should be carried out with 37% phosphoric acid and bonding agent or TPSEP only.

The aim of the present study was to assess *in vitro* the shear bond strength of metallic brackets bonded with TPCC under different enamel conditions, that is, in a conventional way or using TPSEP only, no XT primer, and saliva-contaminated enamel surfaces. The Adhesive Remnant Index (ARI) was also assessed after bracket debonding.

Material and methods

Teeth

Seventy-two healthy human maxillary and mandibular right and left premolars were used, all presenting intact buccal surface with no restoration, caries, fissure or cracks. Teeth that had been submitted to previous application of chemical agents or orthodontic/endodontic treatment were excluded. The teeth were cleaned with periodontal curettes, placed in 0.1% thymol solution for one week and then stored in distilled water at 6ºC until its use. The research project was reviewed and approved by the Ethics Committee of Faculdade de Odontologia de Piracicaba, Universidade Estadual de Campinas, São Paulo, Brazil (process number 128/2008).

Specimen preparation

The roots were centrally inserted into PVC cylinders (20 mm height x 20 mm internal diameter; Tigre, Joinville, SC, Brazil) containing self-curing acrylic resin (Jet; Clássico Artigos Odontológicos Ltda., São Paulo, SP, Brazil) in such a way that the buccal surface of each tooth was positioned perpendicularly to the base. Resin excesses were removed by using a Le Cron spatula (Duflex, Juiz de Fora, MG, Brazil), so that no resin was left in contact with the crown. In order to assure the correct positioning of the tooth, a glass angle square was placed onto the buccal surface and the cylinder.

Bonding procedures

Prior to bracket bonding, the buccal surface of all teeth was cleaned by prophylaxis with slurry of fluoride-free pumice paste (S.S. White, Petropolis, RJ, Brazil) and water in rubber cups at low rotation for ten seconds, flowed by air drying for the same time. The rubber cups were replaced every five uses in order to keep standard procedures.

The specimens were randomly assigned to six groups (n = 12). In Group 1, the brackets were bonded to enamel surface with Transbond XT (control) according to the manufacturer's recommendations (3M Unitek). In Groups 2, 3, 4, 5 and 6, the brackets were bonded to enamel surface submitted to different treatments and using TPCC (3M Unitek), as described in **Table 1**.

The enamel surfaces from Groups 1, 2, 4 and 5 were etched with 37% phosphoric acid gel for 15 seconds, washed and air-dried for equal amounts of time. In Groups 3 and 6, TPSEP was rubbed on enamel for three seconds and gently air-dried. The XT primer used in Groups 1, 2 and 5 was applied to the acid-etched enamel with a microbrush and spread over with a gentle air stream. The saliva used in Group 5 and 6, collected from a donor one hour before the procedure, was applied onto the enamel surface with a dropper and the excess was removed with air stream, keeping the surface contaminated.

Brackets

Seventy-two orthodontic brackets (Code 10.30.208, Morelli, Sorocaba, SPBrazil) with base area of 15.78 mm^2 were centrally positioned onto and pressed against the buccal surface of the teeth by using a pair of pliers (Ortopli Corp, Philadelphia, PA, United States). Composite excesses were removed with a sharp explorer.

Composite photoactivation

A XL 2500 quartz-tungsten-halogen light-curing unit (3M/ESPE, St Paul, MN, USA) was used in all bonding procedures during 40 seconds (10 seconds for mesial, distal, occlusal, and gingival margins) at 500 mW/cm^2, as maintaining a distance of 1 mm from the bracket base. Light intensity for each photoactivation cycle was measured with curing radiometer (Demetron, Danbury, CT, USA).

Shear bond strength testing

After a 24-hour storage in distilled water at 37°C to simulate the oral conditions, the brackets were tested in shear strength in an Instron testing machine (Model 4.11, Canton, MA, USA) at crosshead speed of 0.5 mm/min, with its chisel tip placed onto the enamel/composite interface. The results in kgf were converted into N and divided by the bracket area, as providing values in MPa.

Adhesive remnant index (ARI)

After bracket debonding procedures, each enamel surface was evaluated with a stereoscopic magnifying glass (Carl Zeiss, Gottingen, Germany) at ×8 magnification and characterized according to the Adhesive Remnant Index (ARI) scores established by Artun and Bergland[17], as follows: 0: no composite remaining on the tooth; 1: less

Table 1. Experimental Groups

Groups	Enamel surface preparation	Composite
1	37% phosphoric acid + XT primer*	Transbond XT
2	37% phosphoric acid + XT primer*	Transbond Plus Color Change
3	Transbond Plus Self Etching Primer**	Transbond Plus Color Change
4	37% phosphoric acid	Transbond Plus Color Change
5	37% phosphoric acid + XT primer* + human saliva	Transbond Plus Color Change
6	Transbond Plus Self Etching Primer** + human saliva	Transbond Plus Color Change

* Bonding agent; **Self-etching pimer from 3M Unitek

Table 2. Shear bond strength results

Groups	Mean (Standard deviation)	Tukey's test (5%)
1- Transbond XT (conventional)	24.6 (5.2)	a
2- Transbond Plus Color Change (conventional)	18.7 (5.5)	ab
3- TPSEP + Transbond Plus Color Change	17.5 (4.1)	b
4- Transbond Plus Color Change without primer	19.7 (4.7)	ab
5- Transbond Plus Color Change (conventional) + saliva	17.5 (4.0)	b
6- TPSEP + Transbond Plus Color Change + saliva	14.8 (5.3)	b

Mean values expressed in MPa. Different letters indicate statistically significant difference at 5%.

Table 3. Adhesive Remnant Index (ARI) scores and statistical comparison

Groups	Mean rank	Mean	Statistics
1	28.20	1.41	a
2	37.54	1.75	abc
3	46.08	2.16	bc
4	49.91	2.33	c
5	24.79	1.25	a
6	32.45	1.58	ab

Different letters indicate statistically significant difference at 5%.

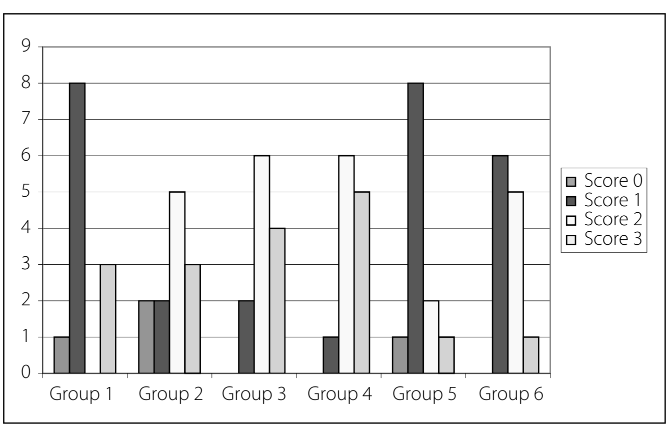

Figure 1. ARI scores.

than half of the composite remaining on the tooth; 2: more than half of the composite remaining on the tooth; 3: all composite remaining on the tooth.

Statistical analysis

Enamel surface preparation was the factor taken into account for statistical analysis. The shear strength bond mean values were subjected to one-way analysis of variance and Tukey's test. Kruskal-Wallis and Student-Newman-Keuls tests were used for comparing the ARI scores. A significance level of 5% was set for all analyses.

Results

Table 2 shows the shear bond strength mean values obtained in the six groups and data statistical analysis. Group 1 had shear bond strength values significantly higher than Groups 3, 5, and ($p < 0.05$), but did not differ significantly from Groups 2 and 4 ($p > 0.05$). No statistically significant differences ($p > 0.05$) were found between Groups 2, 3, 4, 5 and 6.

The mean ARI rank for each group and statistical analysis are presented in **Table 3**. There were statistically significant differences ($p = 0.009$) between groups. The following pairs of groups differed significantly: Groups 1 and 3 ($p = 0.036$); Groups 3 and 5 ($p = 0.021$); Groups 4 and 5 ($p = 0.003$), and Groups 4 and 6 ($p = 0.041$). Most fractures (94.4%) after bracket debonding occurred at the bracket/composite interface, where some amount of remaining composite could be seen on the enamel (**Figure 1**). ARI score 1 (less than half of the composite on the tooth) was predominantly seen in Groups 1, 5 and 6, whereas ARI score 2 (more than half of the composite on the tooth) was more common in Groups 2, 3 and 4. ARI score 0 (no composite remaining on the tooth) was found only in four specimens (**Figure 1**).

Discussion

Transbond XT composite was specifically developed for bonding orthodontic accessories to the enamel. The main advantages offered by this material are: reduced working time, no need of mixing, and good adhesion to enamel[1,8], thus being largely used in clinical orthodontics and experimental studies as controls[3,6,11]. In the present investigation, this composite was used in the Control Group and yielded a mean shear strength value of 24.6 MPa, which confirms its high adhesiveness to dental enamel[8,10,12].

Transbond Plus Color Change (TPCC), which is characterized by its color change form pink to transparent following photoactivation was the composite evaluated in the present *in vitro* study. Though not being the objective of this study, it was observed that its pink color changed even when exposed to room light during the bonding procedures. This fact makes color change a relative advantage as the orthodontist needs time to handle the material, place the accessory correctly, and remove excess material, and all these clinical steps are performed under both natural and artificial light. TPCC's manufacturer provides this information on early color change in lightened environment and such fact was observed in the present study.

Transbond XT and TPCC composites are very similar, but there are small differences in their formulation and the proportion of their compounds[18]. While Transbond XT has 14% BIS-GMA, 9% BIS-EMA and 77% load particles, TPCC has 12, 8 and 80%, respectively. However, these differences in the proportions of their components did not seem to influence the shear strength values, since no statistically significant differences were found between Groups 1 and 2, which used the same composite conventionally.

The hypothesis that changes in the enamel surface preparation interfere with the shear strength values was also tested in this study. In Group 3, TPSEP was applied to dry enamel before using TPCC for bonding the brackets. Since its introduction in 2000, this self-etching agent has been tested in several bonding experiments, mostly yielding adhesive results similar to those of conventional systems[3,6,10,14]. In the present study, the combination between TPSEP and TPCC for dry enamel resulted in a mean shear strength value of 17.5 MPa. Although this value was statistically inferior to that of Group 1 (conventional Transbond XT), such statistical difference was not observed when the same composite was used conventionally (Group 2). This finding indicates that the etching pattern that uses either phosphoric acid or TPSEP did not interfere with the shear strength values[6,10,14,19]. Despite the different types of enamel surface preparations, no statistically significant differences were found between the groups (2 to 6) in which TPCC was used.

The conventional use of adhesive composites requires well-defined steps in order to assure adequate adhesion to enamel. Elimination of one of these steps without compromising the adhesiveness would facilitate the bonding procedure and prevent brackets from debonding. In Group 4, the TPCC composite was used with no previous application of XT primer despite the manufacturer's instructions, yielding a shear strength value of 19.7 MPa. No statistically significant differences were found between Groups 4 and 2, which used the same composite conventionally. The other groups did not show statistically significant differences either. The results obtained in the present study corroborate those of other authors[20,21], who found no significant differences in shear bond strength values regardless of the use of bonding agent. On the other hand, some authors have reported that the bonding agents penetrate more deeply into the enamel, thus forming deeper and wider resin tags in addition to protecting the conditioned dental surface not occupied by the bracket base[20,22,23].

Saliva contamination decreases the adhesion of composites to enamel when they are applied conventionally[5,7,24], resulting, in many cases, in bracket debonding during the orthodontic treatment. In order to reduce the number of cases involving loosen brackets, the manufacturers have developed composite resins, etching agents, and hydrophilic primers that allow adhesion to occur even under conditions of salivary or moisture contamination. In Group 5, TPCC, which is a hydrophilic composite, was used conventionally, but the enamel surface was contaminated by human saliva following application of XT primer. The value of 17.5 MPa was statistically inferior to that of Group 1 (control), although no significant differences had been found between Group 5 and other groups the used TPCC. This similarity between values, including those referring to conventional bonding procedures, is possibly due to the hydrophilic characteristics of TPCC.

TPSEP is another hydrophilic material that was used in Groups 3 and 6 as etching agent; in Group 6, however, the brackets were bonded with TPCC to saliva-contaminated enamel. Group 6 presented the lowest mean shear bond strength value (14.8 MPa) of all groups, but differed significantly only from the Control Group. No statistically significant difference was found when Group 6 was compared to Group 3, in which TPSEP was applied to dry enamel. These findings confirm that moisture can reduce the adhesiveness, but an adequate adhesion may be achieved by means of hydrophilic materials.

In the present study, all groups showed higher shear strength values than those reported by Reynolds[25] despite some statistical differences, which indicates that TPCC can be used for bracket bonding under different enamel conditions as tested here.

In laboratory experiments involving materials for bonding orthodontic accessories to enamel, both differences and similarities regarding shear bond strength values usually do not correspond to the ARI results[4,10]. This fact was also observed in the present study, since statistically significant differences in shear bond strength (**Table 2**) did not correspond to the ARI rank (**Table 3**). It is important to evaluate the ARI scores following debonding in order to verify the amount of composite left on enamel surface, that is, the more adhered the material is, the better (ARI = 3). However, one can be sure that no enamel fracture has occurred at all. In this study, most fractures occurred at the bracket/composite interface with some material left on enamel (ARI scores = 1, 2, and 3), whereas only four specimens had no amount of composite adhered to enamel (ARI score = 0). These results are commonly found in studies using composites as bonding material for orthodontic accessories[4,14,16].

The following conclusions may be drawn: TPCC composite yielded adequate adhesive results for all enamel surface preparations; the type of enamel preparation did not influence the shear strength values obtained with TPCC; when TPCC was used in enamel conditioned with TPSEP and/or contaminated by saliva, the adhesive results were inferior to those obtained with Transbond XT; finally, in all groups, most fractures involved the bracket/composite interface.

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