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Effect of bonding protocol on shear bond strength of orthodontic brackets: An in vitro study

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ABSTRACT

The aim of this study was to evaluate the shear bond strength of bracket composites as a function of the application of flow adhesive prior to the composite and light curing time. Material and methods: Freshly extracted bovine permanent central incisors (50) were acid etched and divided into four groups varying the attachment protocol: (1) no adhesive, composite light-cured for 20s; (2) no adhesive, composite light-cured for 40s; (3) application of adhesive, composite light-cured for 20s; and (4) application of adhesive, composite light-cured for 40s. For comparison, a chemically cured system was used accordingly to the manufacturer instructions. The samples were stored in distilled water (37°C) for 24 hours prior to the shear test (0,75mm/min) and the adhesive remnant index (ARI) was registered for each tooth. Results: The present in vitro findings showed that both variables, application of adhesive and light curing time, influenced the bond strength of orthodontic brackets. Brackets bonded without adhesive present lower resistance to shear forces ($p=0.05$) than the samples bonded with adhesive. Higher bond strength values were found for longer light curing times, though statistical difference ($p=0.05$) was only observed between groups (3) and (4). ARI results show lower scores for extended light curing times. Conclusion: Although the variables in this study significantly affect the shear bond strength of orthodontic brackets, all the experimental groups show bond strength values greater than the normally accepted in the current literature.

Keywords: Orthodontic brackets. Composite resins. Dental bonding. Shear strength.

1. INTRODUCTION

Attaching orthodontic brackets to enamel is a routine clinical procedure in which conventional steps of acid etching, application of an adhesive and a composite (chemical- or light-cured) are carefully taken to assure bonding success. Although the main manufacturers recommend the conventional steps, new methodologies developed to bond orthodontic brackets to dental enamel are being proposed aiming to reduce clinical steps and consequently time and cost of the procedure. Some variations advocate the application of the filled resin directly to the etched enamel without the application of any adhesive [1].

Alternatively, a widely spread new methodology is the use of self etching adhesives. Recently introduced, self etching adhesives combine the acid etching step with an adhesive effect in only one product. The resulting bond strength of self etching adhesives in comparison with conventional composite-adhesives was studied by BISHARA [2]. Lower bond strength values were observed for the self etching Prompt-L-Pop adhesive (3M Unitek, USA) (7,1 ± 4,4 MPa) in comparison to conventional acid and adhesive Transbond XT system (3M Unitek, USA) (10,4 ± 2,8 MPa). However, other results [3] show higher shear bond strength using self etch adhesive Transbond Plus (3M Unitek, USA) developed for orthodontic applications (16 ± 4,5 MPa) than the conventional Transbond XT (3M Unitek, USA) bonding technique (13,1 ± 3,1 MPa). Prompt-L-Pop was developed as a restorative self etchant adhesive for enamel and dentin based on methacrylated phosphoric acids, such as Transbond Plus, an orthodontic self etchant adhesive. Despite having the same active principle, the products differ in methodology of application, what may contribute to such results.

Light activated composites cure by free radical polymerization, depending on the nature of the material itself and the curing parameters, i.e. light irradiance and exposing time. Manufacturers recommend light curing times between 5 to 40 seconds, depending on the type of bracket and the photocuring equipment. Many efforts have been made to clarify the effect of exposing time on bond strength of brackets. Extended light exposure times increases the parameters addressed to improved polymerization [4], such as degree of

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conversion [5], hardness [6] and shear bond strength [7]. Although the direct correlation of increasing light exposure time in polymerization is easily comprehensible, more significant is its effect on the adherence force of brackets clinically.

There is no well-established range of adequate clinical bond strength between bracket and enamel. Bonding strengths of brackets to sound enamel should be high enough to withstand physiological and orthodontic therapeutical forces applied to the bracket but should also be low enough to keep the enamel integrity when bracket debonding is performed. Previous studies [8, 9,10] have suggested 7,1 ± 4,4MPa as clinically acceptable shear bond forces; this range is currently used as a reference in the specialized literature. As discussed by PICKETT [11], many other studies report that the bond strength range of 2,8 to 10MPa is adequate to stand clinical situations with no adhesion failure.

Other studies accessed shear bond strengths in terms of bracket material [1,12,13] composite-adhesive material [14,15] and surface treatment [16,17,18]. The purpose of this study is to investigate the influence of the application of an adhesive prior to the composite and also the effect of the light curing time on the shear bond strength of brackets to the enamel. After the tests, the adhesive remnant (ARI score) was analysed. The null hypotheses were that there would be no differences in the shear bond strength among the composites evaluated.

2. MATERIALS AND METHODS

This study used one light cured composite (Natural Ortho - DFL, Brazil) and one chemical cured composite (Alpha Plast Ortodôntico - DFL, Brazil). Freshly extracted bovine permanent central incisors were stored frozen in distilled water and defrosted at ambient temperature 24 hours prior to sample preparation. The enamel surfaces were visually analysed and only teeth with intact buccal enamel were included. Fifty teeth were selected and embedded in acrylic resin within PVC rings with the buccal surface aligned perpendicular to the mould. The teeth were washed and polished with pumice for 30 seconds. All the teeth were acid etched for 40 seconds with 37% phosphoric gel and thoroughly washed for 40 seconds with water and dried with an air supply free of oil and water.

Metallic brackets for superior incisors (Edgewise 22, Morelli, Brazil) were bonded to the teeth by the same operator. In groups (1) and (2) Natural Ortho was placed on the bracket surface, positioned on the tooth surface, the excess carefully removed and light-cured for 20 seconds and 40 seconds respectively, using a calibrated halogen light unit (Optilux 400, Demetron, USA). In light-cured groups (3) and (4), a thin layer of Alpha Bond Light was applied with a clean brush, Natural Ortho composite was placed on the bracket surface, positioned on the tooth surface, the excess removed and light-cured for 20 seconds and 40 seconds, respectively. In the chemically bonded group, a thin layer of Alpha Bond was applied with a clean brush, Alpha Plast Ortodôntico was placed on the bracket surface, positioned on the tooth surface, the excess removed and let set for 10 minutes. All samples were stored in distilled water at 37°C for 24 hours. The protocols proposed in this study are indicated in Table 1.

Table 1: Protocols to attach brackets to the tooth surface

MATERIAL		ADHESIVE	LIGHT CURING (s)
Natural Ortho (DFL, Rio de Janeiro, Brazil)	Alpha Etch 40s	NO	20
		NO	40
		Alpha Bond Light	20
		Alpha Bond Light	40
Alpha Plast Ortodôntico (DFL, Rio de Janeiro, Brazil)		Alpha Bond	NO

A universal testing machine (DL500, EMIC, Brazil) with a crosshead speed of 0,75mm/min [19] with 500N and 5000N load cells was used to perform the shear tests. The test tool was precisely positioned in the interface between bracket and enamel surface and moved in the inciso-gingival direction. The force (N)

required to debond the bracket was divided by the bracket area (16mm^2) to obtain the shear bond strength (MPa).

After the shear tests, a magnifying glass (CP602, Phoenix, Brazil) was used to observe the composite remnant. The ARI scores developed by ARTÜN and BERGLAND [20] were used in this study: 0 - No composite remained; 1 - Less than half of the composite remained; 2 - More than half of the composite remained and 3 - All the composite remained including the impression of the bracket base. Mean ARI score was calculated for each material. Descriptive statistics, ANOVA and T-student test were used to determine whether the differences are significant between the methodologies studied.

3. RESULTS

The results of shear bond strength for each group are presented on Figure 1. Significant differences were found between the groups (p=0.05). The comparison between methodologies using t-Student test detected that groups (1) and (2) and groups (3) and the chemically cured group are not statistically different (p=0.05).

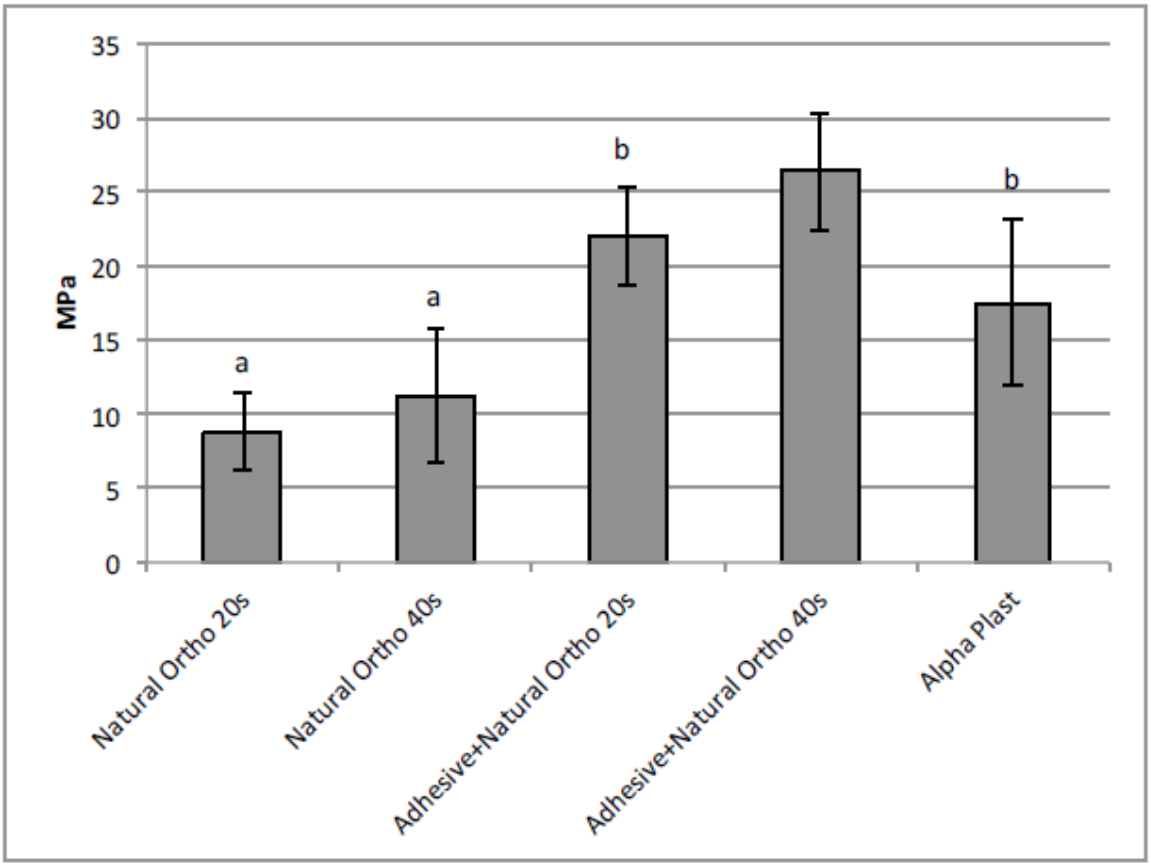

Figure 1: Mean bond strength values (MPa) for the 5 different groups. *Means with the same letters are not significant different.*

Although the mean bond strength increases with higher light curing times, it was not possible to detect a significant difference between groups (1) and (2) using t-Student test. However, there is a statistically detectable difference in bond strength values between the groups using adhesive prior to the orthodontic composite. Groups (1) and (2) where Natural Ortho has been light-cured in direct contact with etched enamel, without the application of adhesive, do not present statistically different bond strength values and were sig-

nificantly different from the groups (3), (4) and the chemically bonded group. Chemically bonded group (Alpha Plast Ortodôntico) bond strength is not statistically different from that of Adhesive+Natural Ortho 20s group (3).

The results of adhesive remnant index (ARI) scores are shown in Figure 2.

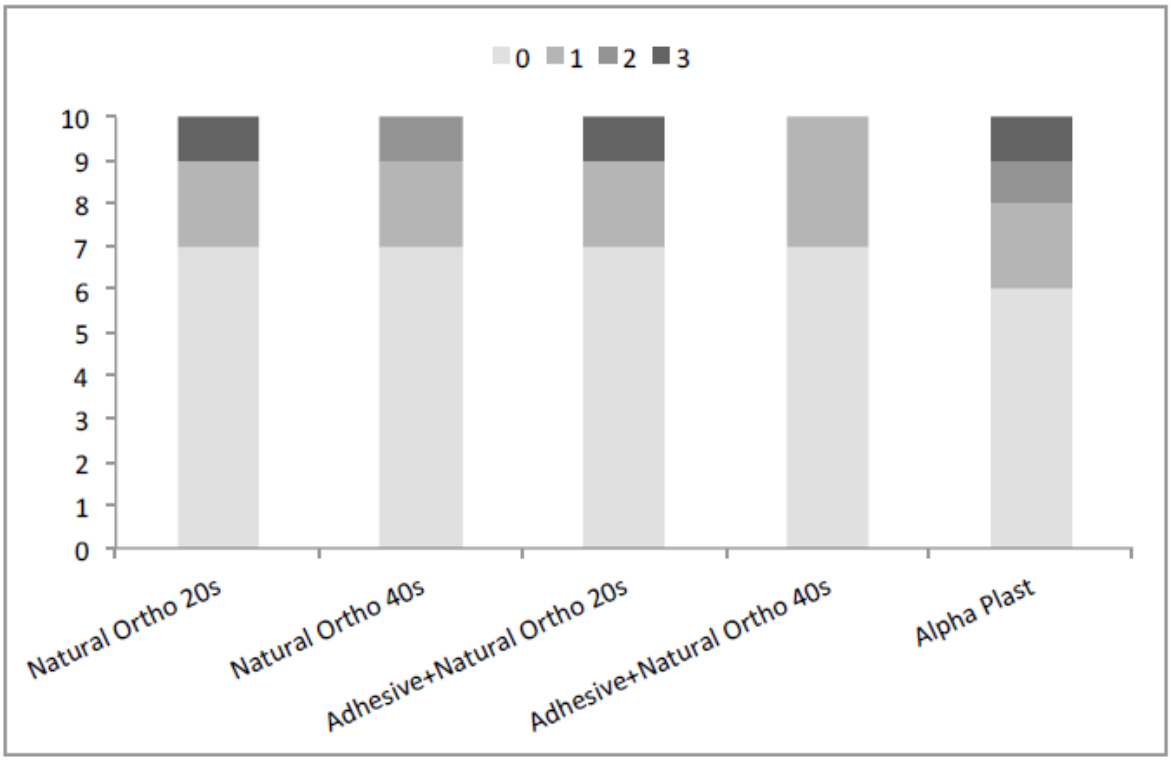

Figure 2: Adhesive Remnant Index (ARI) score repartitions for10 samples within 5 different groups

Most of the scores were reported as no composite remained (score 0). Longer curing time seems to decrease the score 3 where all the composite remained including the impression of the bracket base.

4. DISCUSSION

Adhesion of composites to the tooth structure is a subject of great interest in dentistry and since BUONOCORE [21] introduced in 1955 the principles of adhesive dentistry, many progresses have been achieved. Material composition, particle size distribution, amount of particles, polymeric conversion and light curing times are some examples of variables that control the material characteristics and consequently the adhesion properties. This *in vitro* study proposed an analysis of bracket bonding protocols with orthodontic conventional adhesives.

The acid etching of enamel surfaces removes a thin layer of enamel prisms and creates porosities easily penetrated by low viscosity resins. Therefore, low viscosity resins flow in the open spaces on the etched enamel and form micromechanical bonds [22] easier than high viscous composites. The material used in this study to bond the brackets, Natural Ortho, is a light curing composite filled with particles. It is well known that filled polymers present improved mechanical properties but because of the presence of particles, it becomes more viscous. It is clear that it is more difficult for such a viscous material to penetrate in the etched enamel porosities and low viscous adhesives are then proposed to bond such composites to etched enamels. The results presented in this study show that shear bond strength values (Figure 1) were significantly higher in the groups where the adhesive was applied prior to the composite, independent of the light curing time used (20s or 40s). This is addressed to a deeper penetration of resinous material on tooth subsurface.

For the same light curing time a statistically significant increase is observed (Figure 1) for the shear bond strength of Natural Ortho 20s (group 1) to Adhesive+Natural Ortho 20s (group 3). A similar improvement is observed for the shear bond strength of Natural Ortho 40s (group 2) and Adhesive+Natural Ortho 40s

(group 4). These results demonstrate the clear impact of the use of an adhesive prior to the application of the light curing composite.

A previous clinical study [1] observed no significant differences in the clinical retention of metallic brackets bonded with and without the application of liquid resin prior to a 2 paste chemically cured resin. Approximately 6% of bond failure was found for both groups. The authors claim that there is little doubt that orthodontic bondings without low viscosity resins prior to composites is a viable technique to achieve good enamel adhesion, indicating however, the need for more publications on this subject. In the current study, the shear bond strength for all the groups (Figure 1) are above the clinically acceptable mean present on the scientific literature 7,1 ± 4,4MPa [8, 9,10]. Similarly, these results are preliminary *in vitro* evidences that orthodontic bonding without low viscosity resins prior to light curing composites is a viable technique to achieve good enamel adhesion.

Similar to the results in this study, other groups [4,7] observed higher bond strength of composites to tooth structure increasing the light curing time. Without the application of adhesive, mean shear bond strength increased from Natural Ortho 20s (group 1) to Natural Ortho 40s (group 2) of around 25% (Figure 1). With the application of adhesive, mean shear bond strength increased from Adhesive+Natural Ortho 20s (group 3) to Adhesive+Natural Ortho 40s (group 4) of around 20% (Figure 1). This behaviour is expected since longer light curing times provides more energy for polymeric conversion.

The predominant failure site of all groups is in the interface between the composite and the enamel surface (Figure 2), with no composite remaining on the surface of the tooth (score 0). However, the ARI results also shows that increasing the curing time from Natural Ortho 20s (group 1) to Natural Ortho 40s (group 2) and from Adhesive+Natural Ortho 20s (group 3) to Adhesive+Natural Ortho 40s (group 4) the score 3 is not present, indicating that the material attaches better to the bracket base. Similar ARIs scores were observed for Natural Ortho 20s (group 1) and Adhesive+Natural Ortho 20s (group 3).

The results presented in this study support personal and professional preferences to decide for either chemically or light cured composite to achieve adequate bond strength of brackets to enamel. Shear bond strength of 2 paste chemically cured composite group is not statistically different from the results for Adhesive+Natural Ortho 20s (Figure 1). Current literature [23] cites the lack of publications with evidences to support the use of either chemically or light-cured composite in orthodontics.

Some specific clinical conditions may require higher bond strength than others. For example, young enamel present higher volume of fluids and permeability than mature enamel. That interferes with adhesive procedures [2] and if higher bond strength is necessary, the application of adhesive prior to the composite and higher light curing times can be used.

As a final consideration, under the conditions of this study, increased bond strength of metallic brackets to bovine incisors was achieved with higher light curing times and with the application of adhesive prior to the composite. However, all the groups presented acceptable bond strengths according to the current literature.

5. ACKNOWLEDGMENTS

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