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Effect of Thermocycling on Shear Bond Strength of the Three No-Mixed Bonding Adhesives

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Abstract. To investigate the effect of thermocycling on the shear bond strength of the three no-mixed bonding adhesive.

One hundred and twenty human premolar teeth attached with metal bracket were used in this study. Brackets were bonded to the teeth with three commercial no -mixed bonding adhesive, namely System1+, Rely-a-bond and Unite, 40 teeth for each adhesive group. Each group was divided into two subgroups, one for testing the initial shear bond strength and another at 24 hours after thermocycling following the procedure of adhesive. The three-point bending test was performed to test the shear bond strength of each condition.

Descriptive analysis was used to calculate the shear bond strength and One-way ANOVA was evaluated the difference between each subgroup. The data of shear bond strength were tested for normality by Kolmogorov-Smirnov method. Differences between the groups were then evaluated by One-way ANOVA and a Scheffe's multiple comparison test. Significant difference ($p<0.05$) of initial shear bond strength were found between each other of three no-mixed adhesive.
The shear bond strength of each adhesive after thermocycling was significantly different ($p<0.05$) and higher than the initial shear bond strength of each adhesive.

The shear bond strength of no-mixed adhesive after thermocycling was higher than the initial shear bond strength.

Introduction

Bonding adhesives are able to withstand normal oral forces exerted during mastication and traction force generated by orthodontic appliances.

Bonding systems have undergone continued improvement over time. Presently, many products of bonding agents are available for clinical use, which have differences in their composition, mixing techniques, advantages, disadvantages etc [1-2].

In Thailand, chemical cured systems are currently the most popular for bonding metal and ceramic brackets. They are easier to apply and remove, but not as strong as paste-sealant [3]. With no-mix orthodontic bonding systems, a thin coat of liquid activator is applied to the dried etched enamel surface and to the bracket base. The bonding resin is then applied on the coated base of the liquid activator and the bracket is then firmly placed. This contact initiates polymerization of the resin.

Even though tremendous advances in the development of orthodontic adhesives have allowed orthodontists to bond brackets or attachments to tooth surfaces quite successfully, studies have shown that clinical bond failure still occurs with 5% to 7% of brackets bonded with composite resins for different reasons [4-5]. The purpose of this study is to compare the initial shear bond strength and the shear bond strength after thermocycling 24 hours of the three no-mixed bonding adhesive.

Materials & Method

One hundred and twenty human premolar teeth extracted for orthodontic purposes were used in this experimental study. All teeth were free from carious lesion, restoration, enamel crack, enamel hypoplasia or abnormal buccal surface anatomy that might affect the strength of the enamel. The age and sex of the patients were not considered. The teeth were stored in distilled water to prevent dehydration and bacterial growth. Before testing, all teeth were visually inspected for fractures by observing under a 4 x 10 microscope. If any enamel fracture was found, the tooth would be excluded.

The brackets used in this experiment were 0.022" x 0.028" slot upper and lower premolar standard edgewise stainless steel brackets. (Minidiamond, Ormesh®,Ormco Corporation, CA USA).

The three no-mixed bonding adhesives used in this study were System 1+(Ormco Corporation, Glendora, CA, USA) lot No. 01D8, Rely-a-bond (Reliance Orthodontics Product Inc., Itasca IL,USA) lot No.149173 and Unite (Unitek, 3M dental product, CA ,USA) lot No.010531.

Two thirds of the root of each tooth were cut off and then the lingual surface was grooved with a carborundum disc to aid retention. Each tooth was mounted in a mounting ring with self-cured acrylic resin (Formatray®, KERR Manufacturer Company, USA) to facilitate testing. The mounting ring was made from a PVC tube, 17 mm in diameter, 12.5 mm in high, and 2 mm in thick. The buccal surface of each tooth was kept parallel to the upper surface of the mounting ring, by fixing the tooth in the desired position with sticky wax on the horizontal plane until the acrylic resin was set (Fig 1). The specimens were kept in distilled water until the scheduled testing time.

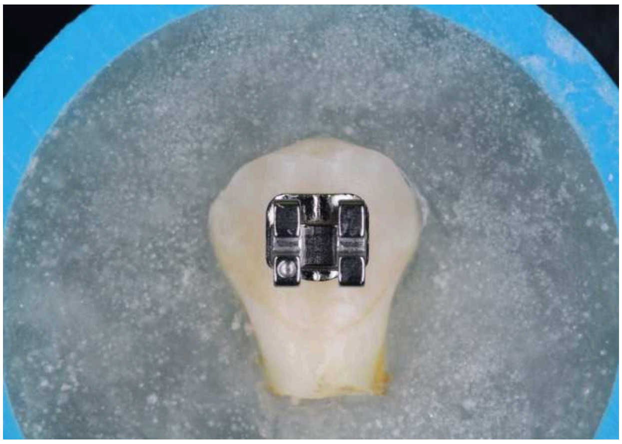

Fig. 1 Tooth was embedded in PVC block

One hundred and twenty specimens were divided into 2 groups for initial shear shear bond strength and 24-hr thermocycling shear bond strength group; each group consisted of 60 samples. Each group was divided in 3 subgroups as described below:

Initial shear bond strength group

- Group 1 (n=20) : bonded with System1+ and tested at 5 minutes (SI1).
- Group 2 (n=20) : bonded with Rely-a-bond and tested at 5 minutes (SI2).
- Group 3 (n=20) : bonded with Unite and tested at 5 minutes (SI3).

The buccal surface of teeth was cleaned by means of a rubber cup with fluoride free pumice and water paste for 15 seconds. The bracket was bonded on the teeth by 3 different adhesives (System1+, Rely-a-bond, Unite). The bonding approach followed the manufacturer's instructions (Fig 2). The bonding of all brackets was performed by the same operator to a standardized technique as in clinical situation and type of bracket was matched with the type of tooth. The loading pressure (the force used to press a bracket on the tooth) used in this experiment was not measured to simulate the clinical practice. Furthermore, from the study of Charuschareonwittaya [6], it was concluded that different loading pressures did not affect shear bond strength of the orthodontic bonding system. After 5 minutes, the bracket was debonded with a crosshead of an Instron testing machine and shear bond strength was recorded.

24 hours thermocycling in the shear bond strength group

Group 1 (n=20): bond with System1+ and tested at 24 hr (ST1).

Group 2 (n=20): bond with Rely-a-bond and tested at 24 hr (ST2).

Group 3 (n=20): bond with Unite and tested at 24 hr (ST3).

After bonding completely, the same procedure as in initial shear bond strength group, all teeth were stored in distilled water at 37^0C for 24 hrs to ensure that the bonding process had complete setting and stored at the temperature as in oral cavity. After that, the teeth were thermocycled between 4^0-56^0C for a total of 1500 cycles. The specimens were stored again in distilled water at 37^0c for 24 hr. The bracket was debonded with the Instron testing machine for recording the shear bond strength.

The shear bond strength testing (Fig 3) was conducted in a universal testing machine (Instron model 4502, serial No.H.3342, High Wycome, UK). Each mounting ring with the specimen was mounted in the lower part of the alignment block, which was fixed to the base of the tester. The upper part of the testing machine was a ram with a knife-edge tip. Then the testing procedure began by bringing down the tip of the upper part at the bracket-resin interface and applyng load until the bracket was dislodged. The Instron was set at a cross head speed of 0.5 mm per minute and loading cell was 10 kN. The shear force generated was measured in Megapascals (MPa) and recorded at the point at which bond failure occurred.

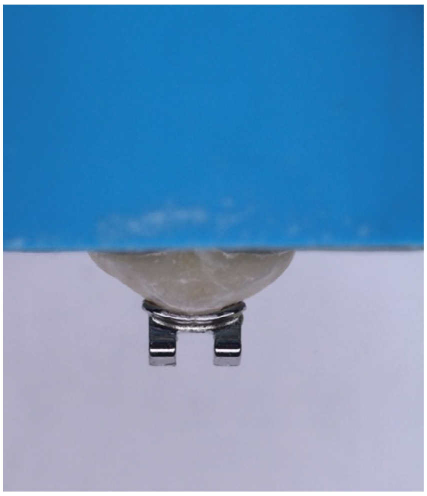

Fig. 2 The bracket bonding.

Fig. 3 The specimen was mounted in the testing machine.

Statistical Analysis

Mean values and standard deviations of the shear bond strengths were computed. The data of shear bond strength were tested for normality using the Kolmogorov-Smirnov method. Differences between the groups were then evaluated by One-way ANOVA and Scheffe's multiple comparison test. The overall test was interpreted for significance at p-value less than 0.05.

Results

The mean shear bond strength and standard deviation of the initial shear bond strength group and 24 hr thermocycling shear bond strength group are shown in Table 1.

The mean of shear bond strength of System1+, Rely-a-bond, and Unite were 2.1, 6.3 and 10.6 MPa, respectively, for initial shear bond strength and 11.7, 16.5 and 18.8 MPa, respectively, for 24- hr thermocycling shear bond strength. Unite produced the highest mean shear bond strength followed by Rely-a-bond and System1+ of the two groups. Significant differences ($p<0.05$) were found in each adhesive of these two groups (Table 2).

Table 1 Descriptive statistics of shear bond strength (MPa) of the initial and 24-hr thermocycling shear bond strength

Group*	**N**	**Initial shear bond strength**		**24-hr thermocycling shear bond strength**		**P**
		Mean	**SD**	**Mean**	**SD**	
System 1+	20	2.1	1.4	11.7	3.3	*
Rely-a-bond	20	6.3	3.7	16.5	7.9	*
Unite	20	10.6	6.2	18.8	8.4	*

*Significant difference at $p< 0.05$

Table 2 The significant difference of shear bond strength (MPa) of the initial and 24-hr thermocycling shear bond strength of each adhesive

Group	SI1	SI2	SI3
SI1	_	*	*
SI2	*	_	*

Group	ST1	ST 2	ST 3
ST1	_	*	*
ST2	*	_	*

Discussion

For method of testing, it was impossible to apply pure shear force for debonding at the bracket/resin or enamel/resin interface. The debonding force should be applied directly to the junction of the bracket and the adhesive, which is very difficult to achieve. There is inevitably some distance away from this junction where the force has to be applied. There is more of a 'peel' element in the debonding force, which will affect the magnitude of the force required to dislodge the bracket. To minimize these differences it is suggested that the samples should be mounted on a universal joint to eliminate variation in the direction of the debonding force [7].

In this study, the investigator also found it was difficult to apply the knife-edge tip of the ram precisely at the junction of the bracket and the adhesive.

The premolar teeth were selected to use as samples in this experiment because they had higher clinical incidence of failure in direct bonded orthodontic attachments than other teeth [8]. Additionally, these teeth are always the teeth of choice to be extracted in the extraction orthodontic cases, it is therefore not difficult to collect them as samples. Fox et al [7]. suggested that it is better to use teeth extracted from adolescent patients than adult patients, because the adult patient teeth present possible adsorption of inorganic or proteinaceous materials, as well as the consequences of various therapeutic procedures and pharmaceutical agents administered to these patients, which may modify the reactivity of the enamel surface layers with an undetermined impact on etching patterns [9]. However, in this experiment, the teeth were collected from many resources, so we could not define from whom the teeth were extracted. Theoretically, bond strength decreases as thickness of adhesive resin increases. This is because of a greater amount of thermal expansion, polymerization shrinkage, trapped volatiles and imperfections (void and cracks). Resin consistency appears to be an important factor in determining the critical resin thickness at which failure begins within the resin. As resin consistency increases, there is less mixing of the primer and paste and less diffusion of the free radicals from the primer/paste interface. Thus, less polymerization occurs, leading to a decrease in bond strength [10]. When comparing among 3 adhesives, Unite had the thickest consistency followed by Rely-a-bond and System1+. Theoretically, System1+, which has the thinnest consistency, would have produced the greatest bond strength; however, the finding revealed that System1+ showed the lowest initial shear bond strength. In this study, the thickness of consistency may not have made a strong influence on bond strength because the operator applied constant force to seat the bracket and tried to obtain the thinnest resin layer, which may provide the optimal mixing of the primer and paste. However, the resin thickness could not be estimated.

Successful clinical bonding should be in the range of 6-8 MPa [11] and should be in the range of 8-20 lbs or 3.5 to 8.9 MPa [12]. In this study, System1+ had the lowest shear bond strength after setting time at 5 min..This reason may be due to the catalyst or initiator system of Unite and Rely-a-bond that is more efficient to polymerize almost completely in a short time. However, it could achieve the optimum shear bond strength if the time passed. The results in Table 1 demonstrated that the initial shear bond increased with time for all adhesive types. When ANOVA was used, the initial shear bond strengths were significantly ($p<0.05$) lower than 24 hr thermocycling shear bond strengths group in all adhesives.

The high shear bond strength values were obtained for the 24 hr. thermocycling. These shear bond strengths show significant difference from each other. The thermocycling teeth samples were subjected to temperature extremes that simulate conditions in the oral cavity [13], with no agreement or standardization of the various thermocycling studies [14].

According to Littlewood et al.,[15] the bond strength of a material with a 5% chance of failure should be at least 5.4 MPa. In the present study, shear bond strengths showed shear stress levels higher than 5.4 MPa at a 5% probability of failure for all adhesives except the System1+ in the initial shear bond strength group. This indicates that using no-mixed adhesive may produce clinically acceptable shear bond strength in the initial and 24-hr thermocycling group except initial shear bond strength of System1+ adhesive.

The results of in vitro testing of orthodontic bracket bond strengths should be interpreted with care, because of the various numbers of specimens and variables involved. Close attention should be paid to the method of bond testing when comparing different papers. Differences in operator technique and the type of bracket used may affect the quality of the bond to the tooth to a larger extent than the type of material used. These factors must be recognized when interpreting the results of in vitro studies [16].

Conclusion

This study was designed to compare the initial and 24-hr thermocycling of the shear bond strength among three bonding agents. Significant differences were found between the initial and 24 hr thermocycling of the shear bond strength of each adhesive. Unite produced the highest shear bond strength followed by Rely-a-bond and System1+ in both conditions.

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