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INFLUENCE OF PROLONGED CONTINUOUS ORTHODONTIC FORCE ON THE SHEAR BOND STRENGTH OF METALLIC BRACKETS BONDED WITH VARIOUS ADHESIVE SYSTEMS

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ABSTRACT

Purpose: To estimate the effect of prolonged continuous force on the shear bond strength (SBS) of orthodontic brackets bonded with different adhesive systems.

Materials and Methods: Eighty premolars were randomly divided into four groups (I, II, III and IV) according to the bonding adhesive used. Orthodontic metal brackets were bonded with one of the succeeding adhesives; Rely-a-bond, Transbond XT primer and adhesive, Transbond Plus self-etch primer (SEP) and Transbond XT adhesive and Smart Bond. Half of the brackets were subjected to 150 g of force for 12 months. All the specimens were thermocycled 1000 times between 5° C and 55° C. A Universal Testing Machine was used to measure SBS.

Results: Transbond XT primer and adhesive exhibited the highest significant SBS value (12.8Mpa). Smart bond showed the lowest value (7.7Mpa). Rely-a-bond and Transbond Plus SEP adhesive systems had middle values (8.8 and 7.8Mpa). There was a significant decrease in the SBS of all studied adhesives ($P<0.05$) accompanied force application ($P <0.05$). Smart Bond showed the higher reduction in SBS while Transbond XT primer + Transbond XT adhesive revealed the lesser reduction.

Conclusion: Application of 150 gram of force for 12 months produced a pronounced negative effect on SBS especially with either SEP or Smart Bond.

INTRODUCTION

Nowadays direct bonding in orthodontic clinics is considered a regular technique. Many attempts to improve the performance of such procedures and reduce the technique sensitivity have been done including the utilization of self-etch primers, [1-4] one-step adhesives, [5] and different polymerization mode (chemical and light). [6-8]

Several factors can potentially influence the bond strength between orthodontic brackets and

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enamel surface such as type of the adhesive system, composition and application time of the etchant, bracket's type and its base style.[9-11] similarly, factors related to the oral environment such as masticatory forces, thermal changes, forces from orthodontic archwires and saliva contamination influenced the bond strength.[12-14] However, the majority of studies about bond strength were focused on its evaluation in first 24 hours after bonding and few studies were concerned about the loading effect on the brackets before testing the bond strength. The effect of applying 120 grams of force 30 minutes after bonding and continued for 24 hours was evaluated in a previous study.[8] The results revealed that early force application yielded a non-significant decrease in shear bond strength (SBS) values. Ireland and Sherriff reported that loading of the brackets for two weeks before testing led to non-significant influence on SBS.[15] Ching et al. investigated the effect of applying a stagnant load of 78 grams after 15 minutes of bonding and kept for two weeks.[16] Their results showed non-significant outcome on both shear and tensile strength of the investigated adhesive. Similarly, Giannini and Francisconi studied the effect of static loads of 30, 70 and 120 grams submitted to orthodontic brackets for 28 days on SBS and no pronounced effects in SBS were found regarding the static forces.[17]

In clinical situation brackets are subjected to continuous prolonged stresses (forces) for several months or years from mastication, occlusion and orthodontic appliances (arch wires, elastics and springs).[18] Although these stresses could be of lesser amount than the static bond strength of the adhesive systems, it could cause microcracks and structural failure, a phenomena called "fatigue". This could produce failure of the bonding and/or microleakage under the brackets during treatment period. The present research was aimed to estimate the impact of 150 gm force applied for 12 months on the SBS of the brackets bonded with various adhesives.

MATERIALS AND METHODS

Sample of this study consisted of eighty human maxillary first premolars recently extracted for orthodontic purposes. The software EpiCalc 2000 version 1.02 (Brixton Books, Brixton, UK) indicated 10 specimens for each group to be a reliable sample size at power 80 % and confidence interval 95 %. Selection criteria included intact buccal enamel, absence of enamel defects, restorations and caries free. This study was done according to the Orthodontic Department research plan which was approved by the Faculty of Dentistry, Mansoura University 's Council. The collected teeth were rinsed and kept in a 0.1 aqueous thymol solution at room temperature for no more than six months. All teeth were inserted in autopolymerizing acrylic resin (Major. Ortho, Major Prodotti Dentari S.P.A. Moncalieri, Italy) inside plastic rings with their buccal surface facing upward. A 0.9 mm stainless steel hook was attached in the acrylic towards teeth apices. Standard twin edgewise metal brackets with mesh base and mean area of 11.85 mm^2 were bonded to the enamel of teeth. Materials used in this study are presented in table 1. The specimens were randomly divided into four equal groups (I, II, III and IV) according to the adhesive system used. After bonding, every group was equally divided into two equal subgroups (A&B). Subgroups A were assigned as control groups (no force applied) while subgroups B were loaded groups (applied force).

In group I: Etching the enamel with 37% phosphoric acid gel for 30 seconds, the teeth were rinsed, dried and then the brackets were bonded to the etched surface according to the manufacturer's instructions. A thin layer of Rely-a-bond primer was painted on the etched surface with a brush and its adhesive to the base of the bracket and pushed against the tooth under a 300 gm compressive force applied with a force gauge (Correx Co, Bern, Switzerland) for 10 seconds.[19] This compressive forces applied to all brackets in the four groups. All the adhesive remnants around the base of the bracket were removed with sharp explorer before setting.

TABLE (1) Materials used and their manufacturers.

Materials	Manufactures
Metal brackets	American Orthodontics, Sheboygan, WI, USA
Titanium coil spring	American Orthodontics, Sheboygan, WI,USA
Phosphoric acid gel	Total Etch, Ivoclar, Vivadent, Schaan, Liechtenstein
Rely-a-bond primer	Reliance Orthodontic Products, Itasca, Ill
Transbond XT primer and adhesive	3M Unitek, Monrovia, Calif
Transbond Plus SEP	3M Unitek Monrovia, Calif
Smart Bond	Gestenco International, Gothenburg, Sweden

In group II: Similar bonding procedures as in group I. Then, Transbond XT primer and Transbond XT adhesive paste was used to bond the brackets to the etched surface following the manufacturer's instructions. Excess adhesive was removed and the adhesive was light-cured (Elipar S10, 3M ESPE, Seefeld, Germany) on each side for 10 seconds.

In group III: the non-conditioned enamel was treated with Transbond Plus SEP according to the manufacturer instructions. The surface was lightly air-dried for 5 seconds. The bracket was bonded and light cured as previously described.

In group IV: enamel was etched, rinsed and kept wet. Smart Bond was applied to the bracket's base and pushed firmly onto the tooth. All adhesive remnants were removed round the bracket sides. All bonding procedures were done by single investigator (YA).

In subgroups B, 150 grams force was delivered to the bonded brackets via a closed titanium coil spring 30 mints after bonding. One side of the coil spring was tied to the bracket, while the other side was pulled and tightened to the metal hook (Figure 1) when the required force was achieved using the force gauge. The force was checked monthly for 12 months. The samples were kept in deionized water at 37 ± 1° C which was changed daily. Finally, the samples were thermocycled 500 cycles between two water baths held at 5° C and 55° C for 20 seconds exposure time in each path. The transfer time between two baths was between 5 to 10 seconds.

Fig. (1) Orthodontic bracket subjected to 150 gram of force via coil spring.

SBS was measured by a Universal Testing Machine (Lloyed, Type 500, Lloyed Instrument, England). Each sample was fixed to the stable lower part of the machine. A sharp steel blade was secured to the mobile upper part of the device. Each sample was exposed to a shear load at a cross head speed of 2 mm/min till failure. The applied load was directed parallel to the long axis of the tooth below the incisal wings of every bracket. The force needed to displace every bracket was calculated in Newton and the SBS was estimated in MPa by dividing the load by the area of the bracket base. SBS measurement was carried out with second investigator (AH) who was not aware of sample grouping.

Next, the quantity of residual adhesive on the each tooth was assessed according to the Adhesive

Remnant Index (ARI).[20] The enamel surfaces and the brackets were examined under Leica M420 microscope (Leitz, Wetzler, Germany) and given score from 0-3. Scores 0 indicate that no bonding resin remained on the tooth, 1 indicates that less than half of the bonding resin remained on the tooth, 2 indicates that more than half of the bonding resin remained on the tooth and 3 indicates all bonding resin remained on the tooth. The scores for adhesive remnant wear given by a third investigator (EN) who also was not aware about the groups.

Statistical analysis

The collected data were statistically analyzed. Mean SBS and standard deviations were assessed for every group. One-way analysis of variance (ANOVA) and LSD tests were utilized to compare between different adhesives within each group. Unpaired student t-test was used to verify the influence of force on SBS for the tested adhesives. Differences in the ARI scores of the adhesives within each group was assessed by Chi-square, while Wilcoxon signed ranks test was utilized to evaluate ARI for the studied adhesives in presence and absence of force application. Differences were considered significant at $P < 0.05$.

RESULTS

Regarding the SBS with no force application, Transbond XT primer + its adhesive system exhibited the maximum strength (12.8±1.9 MPa). On the other hand Smart bond adhesive showed the lowermost value (7.7±1.3 MPa). Rely-a-bond primer + its adhesive system and Transbond Plus SEP + Transbond XT adhesive system showed middle values of 9.4±1.9 MPa and 8.3±1.7 MPa respectively (Table 2 and Figure 2). The results of one-way ANOVA presented significant differences ($P = 0.000$) between the four studied adhesive. The results of LSD test revealed significant difference among SBS of Transbond XT primer + its adhesive system and the other adhesives. As well as, SBS of Rely-a-bond primer + its adhesive system was significantly different from Smart bond ($P <0.05$). Instead, there was no statistically significant difference between SBS of Rely-a-bond primer + its adhesive system and Transbond Plus SEP + Transbond XT adhesive system as well as between Smart bond adhesive and Transbond Plus SEP + Transbond XT adhesive system ($P> 0.05$). Results of t-test revealed that the force application led to a significant decrease in the bond strength for all adhesive systems according to the ($P < 0.05$).

Comparing the SBS of the studied adhesive systems with force application, the results of one-way ANOVA showed significant differences ($P = 0.0001$) among the four studied groups. The results of LSD test showed significant differences between SBS of Transbond XT primer and its adhesive system (11.8±1.8 MPa) and other tested groups as well as between Rely-a-bond primer + its adhesive system (8.2±1.6 MPa) and either Transbond Plus SEP + Transbond XT adhesive system (6.5±1.4 MPa) or Smart bond (6.1±1.2MPa). However, there was no significant difference between SBS of Transbond Plus SEP + Transbond XT adhesive system and Smart bond adhesive ($P > 0.05$).

In overall, cohesive failure was dominant in Rely-a-bond primer + its adhesive and Transbond XT + its adhesive systems, while it became adhesive in general in case of Transbond Plus SEP + Transbond XT adhesive system and Smart bond adhesive. Chi-square test results indicated that there was no significant difference between ARI score of the studied adhesive systems without application of force ($X^2 = 15.186$, P = .086) while there was significant differences ($X^2 = 19.556$, P = .021) with application of force (Table 3). For each adhesive system there was no statistically significant difference ($P> 0.05$) whether force applied or not based on Wilcoxon signed ranks test.

TABLE (2) Mean shear bond strengths (MPa), standard deviations, and results of LSD and t-tests of the four adhesive systems with and without application of force.

	Mean bond strength and standard deviation (MPa)		*t*-test	
	Without application of force	*With application of force*	*t* value	*P*
Rely-a-bond primer + Rely-a-bond adhesive	9.4 ± 1.9^{A}	8.2 ± 1.6	6.368	0.000
Transbond XT primer + Transbond XT adhesive	12.8 ± 1.9	11.8 ± 1.8	5.034	0.001
Transbond Plus SEP + Transbond XT adhesive	8.3 ± 1.7^{AB}	6.5 ± 1.4^{A}	8.838	0.000
Smart Bond	7.7 ± 1.3^{B}	6.1 ± 1.2^{A}	4.102	0.003

Means with the same superscripted letters in each column are not significantly different at *P* ***< 0.05 according to LSD test.***

TABLE (3) Frequency distribution and the results of the chi-squared analysis and Wilcoxon signed ranks test of the Adhesive Remnant Index (ARI) of the studied adhesive systems.

Adhesives	*ARI Scores*								Wilcoxon signed ranks test	
	Without application of force				*With application of force*				Z	*P*
	0	**1**	**2**	**3**	**0**	**1**	**2**	**3**		
Rely-a-bond primer + Rely-a-bond adhesive	0	3	5	2	0	4	4	2	-1.000	.317
Transbond XT primer + Transbond XT adhesive	0	4	3	3	0	4	4	2	-1.000	.317
Transbond Plus SEP + Transbond XT adhesive	3	5	2	0	4	6	0	0	-1.732	.083
Smart Bond	4	4	2	0	5	4	1	0	-1.414	.157
Chi-squared analysis	$X^2 = 15.186$, $P = .086$				$X^2 = 19.556$, $P = .021$					

0: No adhesive left on the enamel. 1: Less than 50% of the adhesive left on the enamel. 2: More than 50% of adhesive left on the enamel. 3: All adhesive left on the enamel

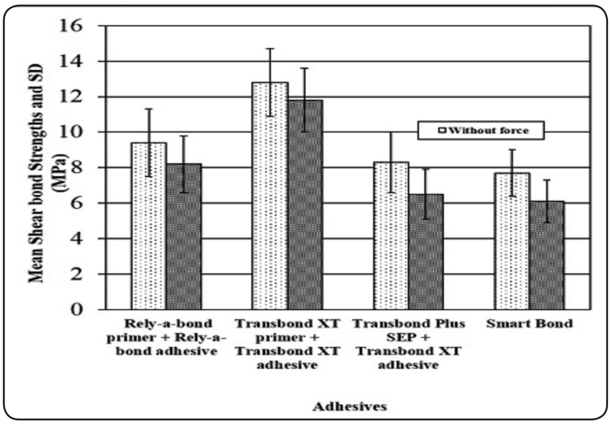

Fig. (2) Mean shear bond strengths and standerad deviation (MPa) of the four adhesive systems with and without application of force.

DISCUSSIONS

The present research was conducted to evaluate the role of prolonged continuous force (150 grams) on bond strength of four different adhesive systems. The force was maintained for 12 months to resemble the clinical treatment period which could last for several months or even few years. In addition, thermal cycling was carried out to stimulate thermal changes in the oral cavity.

The findings of the current experiment revealed that Transbond XT primer + its adhesive system had the highest SBS while Smart Bond had the least one. This finding was in agreement with those of other studies regarding the SBS of SEPs and cyanoacrylate. [3,7,19,21] On the other hand, it was in disagreement with those of Faltermeier et al,[1] and House and Sheriff [22] who reported no significant differences in SBS between SEP and the conventional three steps adhesive systems. Also, it was in contrast to the finding of Örtendahl and Örtengren[4] which revealed that cyanoacrylate performed as well as or better bond strength than composite resins.

The differences in SBS of the studied adhesives may be related to the differences in composition and bonding affinity. In addition, enamel etching by phosphoric acid leading to micro undercuts in the enamel surface through which the adhesive penetrate forming resin tags that enhance the bond strength of the adhesive. This micromechanical retention is less pronounced with SEP adhesive system. Also, light cured adhesive reduces the time for atmospheric oxygen to diffuse into the resin leading to deactivation of the free radicals. Also, the difference in Polymerization shrinkage of the studied adhesive is another factor which may affect the bond strength. It may form contraction strains in the adhesive, which can disturb the seal of the interface between the tooth structure and the adhesive. [23] In addition, increased water sorption, due to storage of the specimens in artificial saliva for one month, and might negatively affect bond strength. Ferracane et al,[24] found a 20% to 30% decrease in fracture toughness of the composites after aging in water at 37°C. Water can infiltrate the polymer and reducing the secondary chemical bonding forces (van der Waals forces) between the polymer chains and decreasing the mechanical properties of the resin. [25] Furthermore, all the specimens in the present study were thermocycled. It was testified that bond strengths of some adhesive resins are decreased following thermocycling due to the differences in coefficient of thermal expansion between bracket, enamel and the adhesives. [26,27]

Regarding the influence of the prolonged force on the SBS, the present findings indicated that, all studied adhesive systems showed a significant reduction in the SBS when they subjected to prolonged continuous force for 12 months (Table 2 and figure 2). Transbond XT primer + its adhesive system showed the least reduction in SBS (7%) followed by Rely-a-bond primer + its adhesive (12%). Conversely, Transbond Plus SEP + Transbond XT adhesive and Smart bond had the highest reduction in SBS (21% & 20% respectively). The applied force (150 g) could lead to microcracks and structural failure, a phenomena frequently identified as fatigue. [28] Fatigue could be affected by stress concentration, corrosion, temperature, overload, microstructure, and residual stresses.[29] The four studied adhesive may have a different resistant potential to fatigue. Andreasen and Stieg reported that a significant decrease (48% to 52%) in vivo shear bond strength when compared with the in vitro one. [30] They referred that to mechanical and masticatory stresses subjected in the oral environment that affect the bond besides moisture or saliva contamination and intraoral thermal fluctuation .

In the present work, there was no significant difference between ARI score of the studied adhesive systems in the absence of force (P = .086) while the application of force led to a significant differences in ARI score (P = .021) as shown in table 3. There was less adhesive remaining on the tooth structure when either self-etch adhesives or Smart bond were used. The low ARI score indicated that these adhesives had weaker bond strength between the adhesive and enamel. Hence, debonding and subsequent polishing would be easier. On the other hand, Transbond XT primer + its adhesive and Rely-a-bond primer + its adhesive had a higher ARI score. Subsequently, the possibility of enamel damage during debonding could be increase. The ideal adhesive systems should provide sufficient bond strength without any deleterious effect on the enamel during debonding.

CONCLUSIONS

Transbond XT primer + Transbond adhesive system revealed significantly greater SBS while Smart Bond exhibited the lowest value among the investigated adhesives. Utilization of 150 gm of force for 12 months significantly decreased the SBS for all studied adhesive systems. However, minimal impact of force is observed with Transbond XT primer + Trans bond adhesive while it was more pronounced with Transbond Plus SEP + Transbond XT adhesive and Smart bond adhesives. Impact of other factors such as working time and the role of saliva contamination on SBS of the adhesive utilized may be evaluated in the future work.

Conflict of Interest

The authors declared they do not have any conflict of interest.

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