



Original Research Article

To Compare Shear Bond Strength of Brackets Using Different Conventional Composites with Self Etching Primer and Its Effect on Early Orthodontic Loading: An In-Vitro Study

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ABSTRACT

Introduction: This study was conducted to evaluate the effect of applying early orthodontic force on the shear bond strength (SBS) of orthodontic brackets bonded with 4 adhesive systems.

Methods: One hundred and twenty stainless steel brackets were bonded to enamel surface of extracted premolars with self etching primer and 4 conventional composites. For each adhesive 15 brackets were bonded without application of force (groups IA, IIA, IIIA, IVA) and another 15 were subjected to a 120gm force with a coil spring (groups IB, IIB, IIIB, IVB). This force was applied 30 minutes after bonding and maintained for 24 hours. Groups IA and IB had Transbond self etching primer (TBP) & Transbond XT adhesive (3M Unitek), groups IIA and IIB had Transbond self etching primer & Orthofix adhesive (Anabond), groups IIIA and IIIB had Transbond self etching primer & Enlight adhesive (Ormco) and groups IVA and IVB had Transbond self etching primer & Light Bond (Reliance Orthodontics). SBS testing was performed by using a universal testing machine (Instron Corporation, Canton, Mass). The results of SBS testing for all adhesives were analyzed by analysis of variance and unpaired Student's *t* test to compare the effect of force on the SBS of each adhesive.

Results: TBP and Transbond XT had the highest values (without force; 9.855 ± 2.4 MPa, with force 9.548 ± 1.596 MPa) and TBP and Enlight had the lowest (without 8.215 ± 1.851 MPa; with force, 6.818 ± 1.742 MPa).

Conclusions: for all studied composites, orthodontic force up to 120gm can be applied within the first hour after bonding with no deleterious effect on bond strength.

Keywords: Shear bond strength, early orthodontic force.

INTRODUCTION

Since the time of Buonocore, bonding of orthodontic brackets to tooth enamel has become an accepted clinical technique.^[1] A typical bonding procedure is based on the alteration of the enamel surface by acid etching followed by application of

adhesive primer and resin.^[2,3] The reduction of number of steps for bonding procedures, reducing harm to the enamel surface, and minimizing bond failures during orthodontic treatment are important from clinical point of view. Self etching primers (SEP's) were

introduced to reduce clinical bonding steps and chair time as they combine etching and priming steps. [4-8] thus they also decrease the possibility of contamination during bonding procedure. In addition, the use of acidic primers decreases the amount of residual adhesive on the enamel surface after debonding. [9,10]

Many factors can affect bond strength between tooth enamel and orthodontic brackets, including type, composition and mode of curing of adhesive, etching time, bracket material and base design, loading mode and oral environment. [9-12] In addition polymerization shrinkage, degree of conversion of adhesive and filler content have a pronounced effect on durability of bonding. [13] Materials used in the oral cavity should be strong enough to withstand both short term and long term forces. [14]

Various studies have evaluated the effect of different testing time on SBS of brackets with various adhesive systems. Although these studies have shown that strength of adhesives increased over time, their initial stable times differed. [15,16]

In clinical orthodontic practice, bonding of brackets and placement of archwires might be done in the same visit. Thus, force is applied to the bracket within first hour of bonding. Regardless of the relatively low magnitude of this force, it could have an adverse effect on the bond strength. It was reported that the polymerization of the adhesive should quickly reach a minimum value to enable the adhesive to resist bonding failure when tying the initial archwire. [17]

In 1997, Ireland & Sheriff, [18] studied the effect of the timing of archwire placement on SBS, both in vitro and in vivo using a no-mix adhesive system. They found that preloading of the brackets 2 weeks before testing had no significant effect on SBS. At the same time no significant difference on SBS was observed in patients

who had arch wires fitted in the same visit as bracket placement and those who had archwires placed after 1 week of bonding.

Similarly, Ching et al, [19] investigated the influence of early loading on both shear and tensile bond strengths of a no-mix adhesive. A static load of 78gm was applied 15 minutes after bonding and maintained for 2 weeks. It was reported that the applied load had no significant effect on either shear or tensile strength of the adhesive.

The aim of our study was to evaluate the effect of applying a continuous orthodontic force for 24 hours (30 minutes after bonding) on the SBS of orthodontic brackets bonded with 4 conventional composites.

MATERIALS AND METHODS

One hundred and twenty maxillary premolars extracted for orthodontic purpose were collected, cleaned and stored in 0.1% aqueous thymol solution. The teeth selected had no cracks, caries, attrition or restorations. They were embedded in self cure acrylic poured in polyvinyl chloride (PVC) pipes, with the buccal surface parallel to the long axis of the pipe. A hook made of 0.9mm stainless steel round wire was fixed in the acrylic towards the apex of the tooth. Standard premolar stainless steel brackets (MBT, Gemini series, 3M- Unitek) were used in this study with an average base area of 10.61mm². The teeth were randomly divided into 8 equal groups of 15 premolars each. The brackets were bonded to teeth by using one of the four adhesives.

In all the groups, the enamel surface was etched with Transbond Plus self etching primer for 3-5 seconds and then a gentle flow of air for 1-2seconds was used to thin and dry the primer, as suggested by the manufacturer.

The adhesives used were: In groups IA and IB, Transbond XT; in groups IIA and

IIB Orthofix; in group IIIA and IIIB Enlight; and in groups IVA and IVB Light Bond.

All adhesives were applied to the base of the bracket and pressed firmly to the tooth. Excessive adhesive was removed before setting.

The medial and distal sides of the brackets were cured (3M ESPE ELISPAR 2500 LIGHT CURE UNIT) for 20 seconds each.

For all the groups, the brackets were placed in their correct position on the enamel surface and pressed with a compressive force of 300gm for 10 seconds by using a force gauge. After bonding all specimens were allowed to bench set for 30 minutes.

In groups IB, IIB, IIIB, IVB, a 120gm force was applied to the bonded brackets with Niti Closed coil spring (9mm-Desires). One end of the coil spring was ligated to the bracket and the other end was stretched and ligated to the metal hook (Fig. 1) until the desired force was reached according to the force gauge. Bond strength testing was done after 24hours with Universal Testing Machine (Instron Corporation, Canton, Mass). The specimens were fixed vertically in a specially designed metal jig anchored to the fixed member of the testing machine. A loop fixed to the upper movable member of the machine was used, to be engaged under the incisal wings of the bracket and parallel to the long axis of each mounted tooth. The specimens were subjected to a shear load at a crosshead speed of 1mm per minute until failure. The load required to dislodge each bracket was recorded in Newton and SBS was calculated in megapascals by dividing the load by the cross-sectional area of the bracket base.

After debonding, the brackets were examined under 10X magnification. The amount of adhesive on the bracket base was assessed by using the adhesive remnant index (ARI). The ARI has a range of 0 (All adhesive on bracket base), 1(more than 50%

of adhesive on bracket base), 2 (less than 50% of adhesive on bracket base), 3 (Entire adhesive left on the tooth with a distinct impression of the bracket base).

Statistical analysis:

Descriptive and inferential statistical analysis has been carried out in the present study. Results on continuous measurements are presented on Mean \pm SD (Min-Max) and results on categorical measurements are presented in Number (%). Significance is assessed at 5 % level of significance.

Analysis of variance (ANOVA) has been used to find the significance of study parameters between three or more groups , Student t test (two tailed, independent) has been used to find the significance of study parameters on continuous scale between two groups (Inter group analysis) on metric parameters. Chi-square/ Fisher Exact test has been used to find the significance of study parameters on categorical scale between two or more groups.

RESULTS

All the groups in this study showed clinically acceptable bond strengths, both with and without force application. The differences in shear bond strengths of all the composites without force application were statistically insignificant and with force application was statistically significant in some of the studied groups.

Without force application: Group IA (Transbond XT) has the highest value of 9.855 ± 2.4 MPa followed by group IIA (Orthofix) with 8.815 ± 1.334 MPa and group IVA (Light Bond) 8.416 ± 1.134 MPa & group IIIA (Enlight) had least mean bond strength of 8.215 ± 1.851 MPa.

With force application: Group IB (Transbond XT) has the highest value of 9.548 ± 1.596 MPa, followed by group IIB (Orthofix) with 7.975 ± 1.429 MPa and group IVB (Light Bond) 7.193 ± 0.666 MPa & group IIIB (Enlight) had the least mean bond strength of 6.818 ± 1.742 MPa.

When we compared the mean SBS values for each adhesive system without application of force, all adhesive systems showed optimal SBS, and the results of the “Student t” test showed no statistically significant differences. ($p \geq 0.05$).

When we compared the mean SBS values for each adhesive system with application of force, all adhesive systems showed optimal SBS, and the results of the “Student t” test showed statistically significant difference ($p \leq 0.05$) in comparison of Transbond XT with Enlight and Transbond XT with Light Bond. Though all composites showed a slight decrease of SBS after force application, their values remained above the recommended value for optimal orthodontic bonding.

ANOVA test revealed statistically insignificant difference between the 4 groups without force as shown in table 1 and significant difference with force as shown in table 2. A subdivision of comparison among composites is given in table 3. A comparison of the mean bond strength values (MPa) is shown in graph 1.

The frequency distribution of ARI scores of the four composites is shown in graph 2.

The failure was mostly cohesive. There was no statistical difference between ARI score for samples with and without force application for all the studied composites. ($P > 0.05$)

Table 1: comparison of SBS of composites: without force application (MPa)

	Transbond XT	Orthofix	Enlight	Light Bond	P value
Min-Max	7.108-16.205	5.872-11.465	6.156-12.355	6.246-10.14	0.060
Mean \pm SD	9.855 \pm 2.4	8.815 \pm 1.334	8.215 \pm 1.851	8.416 \pm 1.134	

Table 2: Comparison of SBS of composites: with force application (MPa)

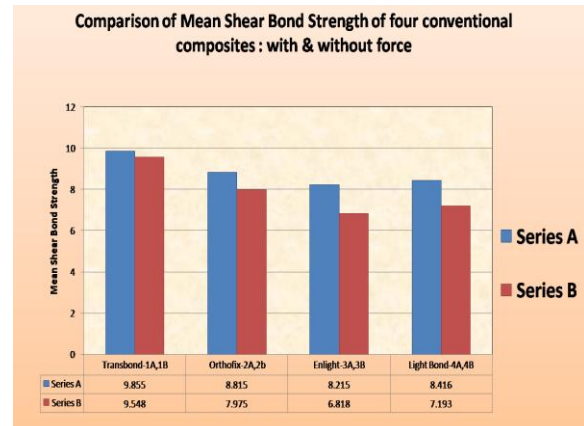
	Transbond XT	Orthofix	Enlight	Light Bond	P value
Min-Max	6.905-13.055	5.586-11.010	3.901-10.251	6.244-8.195	<0.001
Mean \pm SD	9.548 \pm 1.596	7.975 \pm 1.429	6.818 \pm 1.742	7.193 \pm 0.666	

Table 3: Subdividing the comparison among composites: with force application

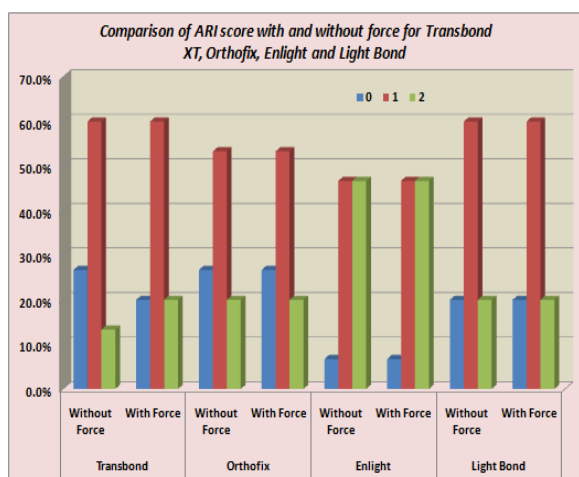
Force	Comparison between	Mean Difference (I-J)	Sig.	
With Force	Transbond XT	Orthofix	1.572	0.019
		Enlight	2.730	<0.001
		Light Bond	2.355	<0.001
	Orthofix	Enlight	1.158	0.127
		Light Bond	0.782	0.439
	Enlight	Light Bond	-0.375	0.887



Fig 1. Example of a bonded bracket with the coil applying force.



Graph 1: comparison of mean shear bond strength of composites with and without force application (MPa)



Graph 2: Comparison of ARI score with and without force application

DISCUSSION

In clinical orthodontic practice, bonding of brackets and placement of archwires can be done in the same visit, particularly rebonding of debonded brackets. Hence force could be applied to the bracket within the first hour of bonding. This force could affect the polymerization of orthodontic adhesive and thus its bond strength. [20] The aim of this study was to determine the development of bond strength of 4 conventional light cured composite, used with self etching primer, subjected to a force similar to clinical situations. The force magnitude used for orthodontic tooth movements varies according to the tooth movement. Here 120gm of force was applied to the brackets 30 minutes after bonding and maintained for 24 hours. This force is considered as maximal orthodontic force.

In this study the conventional orthodontic adhesive, Transbond XT used with Transbond plus self etch primer, showed shear bond strength values which ranged from 7.108MPa to 16.205MPa (mean=9.855MPa), comparable with values reported by Faltermir, [21] 8.67 ± 1.21 MPa.

Bishara, [22] reported a value of 10.40 MPa. Similarly, Arnold, [23] compared the shear bond strength values of Transbond XT

with conventional acid etch procedure and self etching primer, and reported values of 9.7 ± 3.1 MPa and 8.0 ± 1.3 MPa respectively. This proves that Transbond Plus Self-Etching Primer seems to fulfill the requirements for clinical efficiency.

The next highest shear bond strength values were shown by conventional orthodontic adhesive, Orthofix which ranged from 5.872MPa to 11.465MPa (mean=8.815MPa). As no studies have been done on this composite regarding its use in bonding the orthodontic brackets, our results cannot be compared with the previous ones. But the shear bond strength values we have obtained are above the minimum bond strength values which have been mentioned as needed for optimal orthodontic bonding.

Next, Light Bond showed shear bond strength values which ranged from 6.246MPa to 10.140MPa (mean=8.416MPa). Summers, [24] reported, that Light Bond, when used with conventional etching procedure and debonded at 24 hours, was found to have mean shear bond strength (18.46 ± 2.95 MPa). Whereas Light Bond group debonded at 30 minutes had lower bond strength (16.19 ± 2.04 MPa).

Vicente et al, [25] reported that high bond strength values were obtained when brackets were bonded with Light Bond plus Enhance L.C. (16.97 MPa), as recommended by the manufacturer.

In our study, a probable decrease in shear bond strength using Light Bond, could be because usage of Light bond with another company's primer, i.e. Transbond plus self etching primer.

However, Hui-Ping Chen et al, [26] reported values of 9.42 ± 3.12 MPa with Light bond used with conventional etching procedure, which were similar to the results obtained in our study.

Enlight showed the least shear bond strength values which ranged from 6.156 MPa to 12.355MPa (mean=8.215MPa).

However, these values were within the required range of bond strength requiring for clinical use as given by Reynolds. [27] Hui-Ping Chen et al, [26] reported values 8.9 +/- 3.61MPa, which were similar to the results obtained in our study. Similarly, Helen S. I. Grubisa, [5] reported a mean value of 7.3Mpa. Both these studies using Enlight with conventional etching procedure, showed similar values with our study using Enlight with self etching primer, indicating that the use of self etching primer can successfully bond orthodontic brackets as well as when phosphoric acid is used.

Statistical analysis of the ARI scores of the brackets bonded with the composites used in this study did not show much variance between teeth grouped in with and without force application ($P \geq 0.05$), indicating that in both the conditions, the bond failure occurred at enamel-adhesive interface during debonding.

There was a tendency to have less residual adhesive on the enamel surface when self etch adhesives were used. An important requirement of an orthodontic adhesive is the ability to debond by clear separation from enamel surface, leaving no residue. This makes debonding and subsequent polishing much easier. It was reported that greater bond strength was associated with higher ARI scores. [28] On the other hand it was also found that these scores depend not only on bond strength of adhesive but also factors such as, bracket base design, etching procedures and adhesive type. [29]

Comparing the results of SBS values for each adhesive with and without force application, produced a significant reduction in SBS values for some the studied systems i.e. $P < 0.05$ for Transbond XT adhesive vs Enlight and Transbond XT vs Light Bond. But all composites had SBS values above the recommended range for optimal orthodontic bonding.

In our study, differences in SBS values could be attributed to difference in degree of conversion for each adhesive. A high degree of conversion is important to ensure adequate polymerization to sustain the orthodontic forces that might be immediately applied to the tooth at placement and ligation of archwires. Thus it is critical that all components at the adhesive surface undergo maximum polymerization to ensure adequate bond strength. Also, more effective early curing could produce less stress at adhesive enamel interface during application of early orthodontic force.

High degree of conversion values i.e. 80 (average) for the Transbond XT were found by Bayram C. Eorekc et al. [30] Transbond XT consisted of 70.2% fillers by weight which also contributes to the highest SBS values for Transbond XT. Enlight consisted of 63.1% fillers by weight. [31]

Although Light bond has a filler content of 95% by weight, it showed lesser SBS values because of lesser degree of conversion. [29]

Polymerization shrinkage is another factor that can influence the durability of bonding the bracket to tooth structure. It might create contraction stresses in the adhesive that can disrupt marginal seal between adhesive and tooth structure. Although polymerization shrinkage depends on time, most shrinkage occurs in 10 minutes from the start of the reaction and little change occurs after 1 hour. [32] This could explain why applying force after 30 minutes had insignificant effect on SBS.

However, since the in-vitro testing can never simulate the oral conditions precisely, the results cannot be extrapolated to assess the success of these materials and methods tested. Therefore, identifying various parameters included in shear bond testing would make the results more useful for comparative purposes. Thus, the variables present are numerous as stated

above and the results need to be interpreted with care. Extensive clinical trials over extended periods are needed to evaluate the feasibility of the materials tested. The success of the materials for use in orthodontic practice mainly depends on long-term in-vivo studies.

CONCLUSIONS

Regardless of application of force, Transbond XT adhesive had the highest SBS as compared to other composites. Enlight had the lowest value. Application of orthodontic force 30 minutes after bonding for 24 hours gave significant reduction when Light bond and Enlight were compared to Transbond XT, although their values were optimal were orthodontic bonding. Therefore, orthodontic forces upto 120gm can be applied within first hour after bonding without causing bond failure. Further investigation can be done by simulating the study in-vivo, which will provide us a clearer picture of SBS of these adhesive systems.

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