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Comparison of shear bond strength of different bonding materials bonded with primer and without primer - An in vivo study

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ABSTRACT

Objective: To evaluate intra group and intergroup comparison between three different adhesives with and without primer.
Materials and Methods: A total of 120 first premolars were selected randomly for in vivo study and are divided into six groupsGroup 1-(Transbond XT with Primer), Group 2 (Transbond XT without Primer), Group 3 (Orthofix with Primer), Group 4 (Orthofix without Primer), Group 5 (Flowable Composite with Primer), Group 6 (Flowable Composite without Primer). Metal brackets were bonded on teeth by using three different adhesives :Transbond XT, Orthofix and Flowable composite with and without primer. shear bond strength was assessed by modified testing machine with adhesive remnant index(ARI) score for different adhesives
Results: Statistical analysis showed The mean shear bond strength of Transbond XT was maximum (9.77±3.09MPa) followed by that of Orthofix (8.75±2.04MPa) and minimum of Flowable composite (7.82±1.71MPa)and ARI suggested that the fracture occurred between composite and bracket interface.
Conclusion: Transbond XT has the highest shear bond strength while the flowable composite has the least strength but it is more than the optimal strength required hence can be used in bonding. Orthofix showed shear bond strength equivalent to Transbond XT when used without primer.

1. Introduction

Since the advent of the acid-etch technique by Buonocore[1] and the bonding of orthodontic brackets by Newman,[2] various bonding adhesives were developed. The first and most popular bonding resins were chemical curing bonding systems. A major drawback of the self-cure adhesive systems is the inability to manipulate the setting time of the composite resin.[3]

Tavas and Watts[4] first described the use of light-cured materials in vitro for orthodontic bonding. The adhesive is cured under metal-based brackets by direct illumination in the direct bonding technique from different sides and by trans-illumination because the tooth structure transmits visible light. Newer self-etching adhesive materials have been introduced recently in orthodontics to simplify the bonding process by reducing the bonding steps and eliminating the need for etching and priming, thus lessening the risk of contamination and reducing the bonding time.[3] These self-etching primers combine the conditioning and priming agents into one acidic solution and have shown advantages such as reduced loss of enamel, prevention of saliva contamination and less chair time.

Bond strength of orthodontic brackets is an important consideration in orthodontics. Shear bond strength (SBS) is the main factor, which has to be concerned in the

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evolution of bonding materials. An interesting observation is the unit of bond strength being pounds per square inch compared with today's standard unit, Mega Pascal (MPa). The normal conversion would be 1 MPa =145.038 lbs force per square inch. The bond strength of the orthodontic bracket must be able to withstand the forces applied during the orthodontic treatment. Reynolds[5] stated that 5.9–7.8 MPa resistances were sufficient to withstand masticatory forces. Bishara et al[6] compared bond strengths of an acidic primer and composite resin with a conventional adhesive system and found mean bond strengths of 10.4MPa and 11.8MPa, respectively. The SBSs of self-etching primers can vary widely, ranging from 2.8MPa to 16.6MPa.[5] Shear bond strength depends on various factors, including the adhesive properties of the bonding materials, the attachment at the different interphases like the tooth to composite interphase and the composite to bracket interphase, as well as the polymerization of the composite bonding material.[7]

The method of attachment should allow the delivery of orthodontic forces and should be sufficient to withstand masticatory loads. In the direct bonding of orthodontic brackets, current bonding systems involve etching the enamel surface, flowing an unfilled or lightly filled liquid resin into the etched surface, and then using a filled resin on the bracket base to form the final bond between the bracket and the tooth before self-curing or light-curing the adhesive. Currently, clinicians use various methods for bonding orthodontic brackets on teeth i.e. application of primer only on the tooth surface as well as the bracket bases. However, there is a variation in the bonding methods used by clinicians.

The purpose of the present study to evaluates intragroup and intergroup comparison between three different adhesives with and without primer.

2. Materials and Methods

The study was conducted in the orthodontic department and the subjects participating in this clinical trial were randomly assigned to the clinician from the pool of patients seeking orthodontic treatment. The particpants were assigned to the single operator and all the brackets were bonded and debonded by the same operator. The study was approved by Institutional Human Ethical Committee and Institutional Research Developmental Committee of the institute.

2.1. Experimental groups

A total of 30 patients undergone extraction of all first premolar (120 teeth) were selected. The inclusion criteria consisted of willingness to participate in this clinical trial through the signing of an informed consent form approved by the Institutional Human Ethical Committee and Institutional Research Developmental Committee of college The informed consent contained a detailed explanation of the procedures involved in the study. The subjects included patients requiring extraction of four first premolars. Exclusion criteria was based on teeth having caries or enamel defects and decalcification of the enamel, teeth having surface cracks, teeth having fluorosis, non vital teeth and teeth fractured because of trauma. The teeth (120)were divided equally into six groups based on the adhesive system used as follows [Table 1]

Group 1-Transbond XT with Primer
Group 2 Transbond XT without Primer
Group 3 Orthofix with Primer
Group 4 Orthofix without Primer
Group 5 Flowable Composite with Primer
Group 6 Flowable Composite without Primer.

All Armamentarium used for bonding has been shown in. The teeth were cleaned and pumiced by using a rubber cup with fluoride-free paste for 10s, thoroughly washed with water, and air-dried. Stainless steel 3M victory series premolar brackets were used, with the 0.022 slot. The surface area of bracket base was 11.15 mm^2 and the mesh size was 80 gauge. The teeth were etched for 60 seconds and then rinsed and air dried, then brackets were bonded to the teeth with the respective adhesive and cured for 40 seconds with primer(cured for 20 seconds) and without primer according to the group division and were debonded after 24 hours with an invivo debonding device[Table 2] which is time tested and was used by Pickett et al[8] with a modified debonding plier [Figure3] to debond the brackets on patient's teeth. Shear bond strength was calculated on the digital gauge.

2.2. Assessment of the adhesive remnants on teeth and enamel surface after debonding

Once the brackets had been debonded9, the enamel surface of each tooth was examined by trans-illumination of the buccal surface of teeth using fiber optic light $\times 10$ magnification lens to determine the amount of adhesive left on each tooth. The adhesive remnant index (ARI) scores were recorded according to the original description of Artun and Bergland10, with the following scale:

- 0, no residual adhesive left on the tooth.
- 1, less than half of the adhesive left on the tooth.
- 2, more than half of the adhesive left on the tooth.
- 3, all adhesive left on the tooth, with a distinct impression of the bracket mesh.

Selected surfaces of each group were also examined under SEM (ZEISS DSM 950, Germany) to observe enamel surface after debonding.

2.3. Statistical Analysis

The mean SBS of the six groups was compared by one-way analysis of variance (ANOVA) and the significance

of the mean difference between the groups was done by Tukey post-hoc test. Discrete (categorical) ARI scores of six groups were compared by Chi-square test. A two-tailed (α = 2) $P < 0.05$ was considered as statistically significant.

3. Results

On comparing the shear bond strength of bonding agents with primer [Table 2][Graph2] among 20 specimens each of Transbond XT, Orthofix and Flowable composite shear bond strength were maximum for Transbond XT (11.82±2.87MPa) followed by that of Orthofix (10.02±1.56 MPa) and minimum for Flowable composite (9.11±1.18 MPa). The difference of shear bond strength of above bonding agents (with primer) was found to be statistically significant.

On comparing between the group difference of shear bond strength [Table 3] maximum difference was observed between Transbond XT and Flowable composite (2.72±0.63MPa) followed by between Transbond XT and Orthofix (1.81±0.63) while the minimum difference was observed between Orthofix and Flowable composite. Between-group differences of Transbond with other two bonding agents (Orthofix and Flowable composite)[Table 4] were found to be statistically significant. Order of shear bond strength was Transbond XT with primer > Orthofix with primer >Flowable composite with primer.

Among 20 specimens [Table 5] each of Transbond XT, Orthofix and Flowable composite without application of primer shear bond strength were maximum for Transbond XT (7.71±1.59MPa) followed by that of Orthofix (7.47±1.64MPa) and minimum for Flowable composite (6.54±1.06MPa). The difference of shear bond strength of above bonding agents (without primer) was found to be statistically significant.

On comparing between the group difference of shear bond strength[Table 6] maximum difference was observed between Transbond XT and Flowable composite (1.17±0.46MPa) followed by between Orthofix and Flowable composite (0.93±0.46) while the minimum difference was observed between Transbond XT and Flowable composite. Between-group differences were found to be statistically significant only between Transbond and Flowable composite. Order of shear bond strength was Orthofix without primer >Transbond XT without primer >Flowable composite without primer.

The shear bond strength of specimens with primer[Table 7] was significantly higher as compared to its counterpart without primer for all the bonding agents i.e. Transbond XT (11.82±2.87 Vs.. 7.71±1.59MPa), Orthofix (10.02±1.56 Vs.. 7.47±1.64) and Flowable composite (9.11±1.18 Vs.. 6.54±1.07MPa).

The difference in Adhesive remnant index of specimens[Table 8] Transbond XT with primer and without primer was not found to be statistically significant. Among specimens bonded with Orthofix bonding agent with primer majority had ARI score 1 (60.0%) followed by score 0 (30.0%) and only 10.0% had ARI score 2 while among specimens bonded with Orthofix bonding agent without primer majority had ARI score 1 (60.0%), none had score 0 and rest 40.0% had ARI score 2. The difference in ARI of specimens of Orthofix with primer and without primer was found to be statistically significant (p=0.009). The difference in Adhesive remnant index of specimens Flowable composite with primer and without primer was not found to be statistically significant. The proportion of specimens with ARI score 2 was significantly higher among without primer as compared to with primer.

4. Discussion

Enamel bonding for orthodontic applications was introduced in 1965 and was considered a significant milestone in orthodontic treatment. As reported by Owens and Miller[9] direct bonding of orthodontic brackets to enamel was made a reality by Buonocore[1] Bowen[10] and Tavas and Watts.[4]

New technologies using novel materials are constantly evolving to improve the quality of the bond between the brackets and tooth or artificial subjects.[11,12]

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.[13–16] Eliades T. et al[11] stated that in addition to polymerization shrinkage, the degree of conversion of adhesive and filler content had a pronounced effect on the durability of bonding. Trites B et al[19] stated that materials used in the oral cavity should be strong enough to withstand both short-term and long-term forces.

In this study the Transbond XT (with and without primer) showed higher values of shear bond strength which ranged from 5.47MPa to 16.28MPa (mean 9.69MPa) [Table 2][Graph2] comparable with values reported by Falter Meir[17] who concluded that Transbond XT with primer has the highest strength of 8.67 ± 1.21 MPa, Bishara[18] (10.40MPa ± 2.1MPa). Other studies also showed the similar result like Arnold[19] (9.7 ± 3.1MPa and 8.0 ± 1.3MPa) Tecco et al[20] (23.23 MPa + 5.23 MPa), D'Atillio et al[21] (23.47 MPa±4.86 MPa), Rock and Abdullah[22] (8-23 MPa) respectively.

Orthofix (with and without primer) showed the shear bond strength which was equivalent to Transbond XT which ranged from 5.15MPa to 12.60MPa (mean=8.75MPa) [Table 2][Graph 2] which are similar to the study conducted by Ashita Talwar et al[23] in which the shear bond strength values of Orthofix ranged from 5.872MPa to 11.465MPa (mean=8.815MPa).

Table 1: Distribution of Specimens

	Bonding agent	No. of specimens	Percentage
A-	Transbond XT	40	33.34
	(1) With primer	20	16.67
	(2) Without primer	20	16.67
B-	Orthofix	40	33.34
	(3) With primer	20	16.67
	(4) Without primer	20	16.67
C-	Flowable composite	40	33.34
	(5) With primer	20	16.67
	(6) Without primer	20	16.67

Table 2: Comparison of Shear Bond Strength of Bonding agents with Primer

Group	No. of specimens	Min.	Max.	Mean	S.D.
Transbond XT	20	6.47	16.28	11.82	2.87
Orthofix	20	7.54	12.60	10.02	1.56
Flowable composite	20	6.55	10.70	9.11	1.18
Total	60	6.47	16.28	10.32	2.27

F=9.538; p<0.001 *(ANOVA)

Table 3: Comparison of shear bond strength of bonding agents with primer

Group	No. of specimens	Min.	Max.	Mean	S.D.
Transbond XT	20	6.47	16.28	11.82	2.87
Orthofix	20	7.54	12.60	10.02	1.56
Flowable composite	20	6.55	10.70	9.11	1.18
Total	60	6.47	16.28	10.32	2.27

F=9.538; p<0.001 *(ANOVA)

Table 4: Between Group (Bonding Agents with Primer) comparison of Shear Bond Strength (Tukey HSD)

	Mean difference	S.E.	'p'
Transbond XT Vs..Orthofix	1.81	0.63	0.016*
Transbond XT Vs..Flowable composite	2.72	0.63	<0.001*
OrthofixVs..Flowable composite	0.91	0.63	0.328

Table 5: Comparison of Shear Bond Strength of Bonding agents without Primer

Group	No. of specimens	Min.	Max.	Mean	S.D.
Transbond XT	20	5.47	11.10	7.71	1.59
Orthofix	20	5.15	10.86	7.47	1.64
Flowable composite	20	5.12	8.65	6.54	1.06
Total	60	5.12	11.10	7.24	1.52

F=3.579; p=0.034 (ANOVA)

Table 6: Between Group comparison of Bonding Agents with Primer (Tukey HSD

	Mean difference	S.E.	'p'
Transbond XT Vs..Orthofix	0.24	0.46	0.866
Transbond XT Vs..Flowable composite	1.17	0.46	0.037
OrthofixVs..Flowable composite	0.93	0.46	0.117

Table 7: Comparison of Shear Bond strength of Bonding Agents with primer and without primer (Student 't' test)

Bonding Agent	With Primer (n=20)		Without Primer (n=20)		Significance of Difference	
	Mean	SD	Mean	SD	't'	'p'
Transbond XT	11.82	2.87	7.71	1.59	5.607	<0.001*
Orthofix	10.02	1.56	7.47	1.64	5.023	<0.001*
Flowable composite	9.11	1.18	6.54	1.07	7.204	<0.001*

Table 8: Comparison of ARI with and without primer

Group	With Primer						Without Primer						Statistical significance (Mann Whitney U test)	
	0		1		2		0		1		2		Z	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
Transbond XT	6	30	12	60	2	10	3	15	10	50	7	35	1.862	0.096
Orthofix	6	30	12	60	2	10	0	0	12	60	8	40	2.968	0.009
Flowable Composite	3	15	13	65	4	20	3	15	8	40	9	45	1.271	0.253
Overall	15	25	37	61.7	8	13.3	6	10	30	50.0	24	40.0	3.482	<0.001

The shear bond strength values shown by Flowable composite (with and without primer) ranged from 6.12MPa to 10.70MPa (mean=8.26MPa) [Table 2] which were similar to the values obtained by Kumar KS et al[24](11.0MPa, mean 2.87), Owais Khalid et al[25](10.54MPa ± 1.86MPa), Aasrum et al[26] (6.4MPa) and Bradburn and Pender[27] (7.22MPa ± 2.11MPa), Joseph and Rossouw[28] (17.80MPa ± 3.54MPa) and Schmidlin et al[29] (16.6MPa ± 6.4MPa), Ryou DB et al[30](7.2 and 8.3Mpa).

However, the shear bond strength of three adhesives, Transbond XT, Orthofix and Flowable composite on comparing was found to be statistically significant with p=0.022.

On comparing the shear bond strength between Transbond XT, Orthofix and Flowable composite the shear bond strength of Transbond XT and Orthofix were equivalent and least bond strength was observed in the Flowable composite as compared to the other two adhesives which showed similarity with the study performed by Kumar KS et al.[24]

On group comparison among bonding agents with primer [Table 3][Graph3] the bond strength of Transbond XT ranged from 6.47MPa to 16.28MPa (mean 11.82MPa), Orthofix ranged from 7.54MPa to 12.60MPa (mean 10.02MPa) and Flowable composite ranged from 6.55MPa to 10.70MPa (mean 9.11MPa) showed that the Flowable composite with primer has least shear bond strength as compared to the other two adhesives and there was a significant difference ($p<0.001$) on comparing the flowable composite with Transbond XT [Table 4] in which he concluded that the shear bond strength of Transbond XT was 11.64± 3.68MPa which was significantly higher as compared to the strength of Flowable composite which was (9.42±2.21) MPa.

On group comparison among bonding agents without primer [Table 4][Graph 4] the bond strength of Transbond XT ranged from 5.47MPa to 11.10MPa (mean 7.55MPa), Orthofix ranged from 5.15Mpa to 10.86MPa (mean 7.47MPa) and Flowable composite ranged from 6.12MPa to 9.65MPa (mean 7.41MPa) showed that the Flowable composite with primer had least shear bond strength as compared to the other two adhesives and on comparing the Transbond XT with Orthofix and Flowable composite 'p' was found to be 0.984 and 0.084 whereas 'p' was 0.989 when Orthofix and Flowable composites were compared.

The comparison among the three adhesive groups with primer and without primer [Table 7]. The mean shear bond strength of Transbond XT with primer was 11.82MPa and without primer was 7.55MPa this showed a highly significant difference with 'p'<0.001 which was similar to the study performed by Bishara et al.[18] The mean shear bond strength of Orthofix with primer was 10.02MPa and without primer was 7.47MPa this showed a highly significant difference with 'p'<0.001 which was similar to the study performed by Ashita Talwar et al.[23]

It was considered that the results reported in the present study provided a more accurate account of actual in-vivo bond strengths when compared with other studies that rely on in-vitro results to assess bond strengths required for clinical success.

These findings may be of assistance to the bracket and adhesive manufacturers by enabling them to develop products based on actual in-vivo bond strengths. This, in fact, could help maximize clinical success and, at the same time, minimize the risk of enamel fracture during debonding.

There were a few limitations in our in-vivo study design. Every effort was made to isolate the oral environment but whatever the measures were taken isolation method could not be prepared in totality, this was because the biodegradation in the oral cavity is the result of a combination of disintegration and dissolution in saliva, chemical, and physical degradation, wear caused by chewing food, erosion by the food itself, and bacterial activity and thus it was such a complex interaction of processes that it could not be reproduced fully.

Since this study showed the effect of shear bond strength within in-vivo design so, for further research, we can enhance these results by performing the study on recent bonding materials and also with advanced technologies.

5. Conclusions

1. Shear bond strength is essential factor to determine the bonding strength of an adhesive. The present study is conducted to assess the bond strength of three different adhesives with and without primer. The study concluded that
2. There was a significant difference between the three adhesives used with primer in which Transbond XT has the highest shear bond strength and flowable composite having the least strength.
3. There was a significant difference in between Transbond XT and flowable composite when used without primer while the shear bond strength of Transbond XT and Orthofix were equivalent.
4. The shear bond strength of three adhesives compared with and without primer individually had a significant difference showing that the sealant creates a mechanical bonding between the enamel and adhesive interface and also forms a pellicle formation inside the etched enamel which enhanced the bond strength of adhesive.
5. This study shows the values of shear bond strength which is close to the actual clinical bond strength as the method of research being in vivo which is better than other studies conducted in vitro. Variations from the other studies are due to inconsistent methods and multifactorial considerations

6. Source of Funding

None.

7. Conflict of Interest

None.

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