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A comparative study of shear bond strength of four different light cure orthodontic adhesives: An in vitro study

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ABSTRACT

Objective: To compare the shear bond strength and Adhesive Remnent Index (ARI) of metal brackets using four different bonding systems: Heliosit Orthodontic Bonding Material (Ivoclar Vivadent), Ormco Enlight Light Cure Adhesive, Transbond XT Light Cure Adhesive (3M UNITEK) and Light cured Orthofix (Anabond Stedman Pharma Research (P) Ltd.

Materials and Methods: In the present study 120 extracted sound human upper bicuspids were taken and divided into four groups. Group 1: Heliosit Orthodontic Bonding Material (Ivoclar Vivadent), Group 2 : Ormco Enlight Light Cure Adhesive ,Group 3: Transbond XT Light Cure Adhesive(3M UNITEK) and Group 4: Light cured Orthofix (Anabond Stedman Pharma Research (P) Ltd. In all the groups (n = 120) orthodontic metal brackets were bonded with the four different light cure adhesives respectively and all the samples were evaluated for shear bond strength using Instron(3366) universal testing machine at a cross speed of 1 mm/min. The bracket failure mode was examined using Adhesive Remnant Index (ARI). The Inter group comparison (>2 groups) was done using one way ANOVA followed by pair wise comparison using post hoc test. Comparison of frequencies of categories of variables with groups was done using Chi square test. For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

Conclusion: It was concluded that the mean shear bond strength of the Transbond XT was highest among the four adhesives studied. However all the adhesives tested exhibits adequate bond strength for clinical use and ARI scores was nearly same for the Transbond and Enlight adhesives studied.

1. Introduction

Since the innovation of bonding bracket, constant research base finding has led to the development of progressively advanced orthodontic adhesives and made the direct bonding procedure more successful. The bond strength of the adhesive and attachment should be such that, it should be able to withstand the forces of mastication, the stresses exerted by the arch-wire and patient abuse, as well as allow for control of tooth movement in all three-planes of space.[1] At the same time, the bond strength should be at a level to allow for bracket debonding without causing damage to the enamel surface.[2] The Adhesive Remnant Index (ARI) plays an important role in determining the bonding potential of various adhesives by determining the nature of bond failure. It was introduced by *Artun and Bergland* (1984).[3]

Buonocore[4] introduced the technology that led to the concept of direct bonding in orthodontics. Ten years later, Newman[1] described acid-etching technique which enhanced the mechanical adhesion of orthodontic brackets on the enamel surface of teeth. The most widely accepted bonding system in contemporary orthodontic practice is the

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acid etched/composite technique.[5] Recently, several visible light–cured orthodontic adhesives have been illustrated, their main benefits being high early bond strength, minimal oxygen inhibition and enough working time. Previous studies have introduced a resistant force of 6 to 8 MPa as an appropriate one to avoid single failure of the bracket bonding.[1]

The typical bonding procedure consists of alteration of the enamel surface by acid etching technique followed by the application of adhesive primer and resin. From the clinical point of view the reduction in the number of steps for bonding, reduction of any damage to the enamel surface, and minimizing bond failure during orthodontic treatment is very important. There are several factors that can affect the bond strength between tooth enamel and orthodontic brackets. These include type, etching time, composition and mode of curing of adhesive, bracket material, bracket base design, loading mode and oral environment.[6] In addition polymerization shrinkage, degree of conversion of adhesive and filler content have a pronounced effect on durability of bonding. It is imperative that the materials used in the oral cavity are strong enough to withstand both short term and long term forces.

Few studies in orthodontic fields have been published on this subject but none of them have compared the effects of these four different light cure adhesives together on the shear bond strength (SBS) of orthodontic brackets. Hence, the present in-vitro study was undertaken to compare the shear bond strength of four most commonly used light cure orthodontic bonding adhesive: Heliosit Orthodontic Bonding Material –Ivoclar Vivadent,Ormco Enlight Light Cure Adhesive-Ormco, Transbond XT Light Cure Adhesive (3M UNITEK), Light cured Orthofix (Anabond Stedman Pharma Research (P) Ltd. This study also evaluates the quantity of adhesive remaining on the tooth surface after debonding of brackets.

2. Materials and Methods

Around 120 freshly extracted non-carious human maxillary premolars were collected and stored in artificial saliva. Before testing, the teeth were mounted on a 4-cm long acrylic cylinder with an internal diameter of 3 cm with different colour codings.

2.1. Preparation of the samples for shear bond strength

The teeth were divided into four groups (n = 30), and maxillary premolar brackets (3M Gemini, MBT 0.022 slot, Metallic) were bonded on their buccal surfaces, as per manufacturers' instructions. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste.

2.1.1. Group 1 (n = 30)

The surface of the enamel of premolars was etched for 15s with 37% phosphoric acid (3M ESPE Scotchbond etching gel, St Paul, MN), washed with water, and dehydrated with moisture-free squeezed air for 20 s. The orthodontic brackets were bonded using Transbond XT adhesive (3M/Unitek, Monrovia, Calif) followed by photopolymerization (LED, Woodpecker) for 40 s (10 s on each side).

2.1.2. Group 2 (n = 30)

One coat of Ortho Solo was applied to the etched enamel. No drying or curing step applicable. Immediately the orthodontic brackets were bonded with Enlight light cure adhesive followed by photopolymerization as in Group 1.

2.1.3. Group 3 (n = 30)

One layer of Anabond Stedman Orthofix primer was applied to the etched enamel. The surface was light cured for 10s and the orthodontic bracket was bonded immediately with Orthofix adhesive followed by photopolymerization as in Group 1.

2.1.4. Group 4 (n = 30)

The orthodontic bracket was immediately bonded with light cure adhesive Heliosit followed by photopolymerization as in Group 1.

2.2. Samples testing

All the prepared samples subjected to shear bond strength testing were preserved in artificial saliva at room temperature for 24 hours. Each sample was subjected with shear load in a universal testing machine, (Instron Machine Model 3366, at BIT Meshra, Ranchi, Jharkhand) applied by a knife-edged blade at a cross-head speed of 1 mm/min. The applied force was directly parallel to the external surface of the tooth on top of the each bracket base and a load of shear bond strength was recorded at the point of debonding. This force (kilonewton) was converted into MPa by the following formula. MPa = Force (in N)/Surface area (In mm2). The bracket base was 10.61 mm^2according to the company specification.

2.3. Adhesive remnant index (ARI)

The enamel surfaces of all the test samples were examined after shear bond strength estimation under a SEM model in use is JSM6390LV(Jeol,Japan) at BIT Meshra Ranchi to determine the amount of the adhesive resin remaining on the surface and then classified according to the ARI. The ARI scores were arranged according to the criteria given by Artun and Bergland[1] from 0 to 3, with 0 indicating no composite left on the enamel; 1, less than half of the composite left; 2, more than half of the composite left; and

3 all of the composite left on the tooth surface.

2.4. Statistical analysis

Data obtained was compiled on a MS Office Excel Sheet (v 2010, Microsoft Redmond Campus, Redmond, Washington, United States). Data was subjected to statistical analysis using Statistical package for social sciences (SPSS v 21.0, IBM). Descriptive statistics like frequencies and percentage for categorical data, Mean & SD for numerical data has been depicted.

1. Inter group comparison (>2 groups) was done using one way ANOVA followed by pair wise comparison using post hoc test.
2. Comparison of frequencies of categories of variables with groups was done using chi square test.

For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

3. Results

The descriptive statistics (mean and SD) of shear bond strength was measured for all the groups. The highest mean SBS was recorded in Transbond XT. To find out the significant difference in the mean SBS among all groups Inter group comparison (>2 groups) was done using one way ANOVA followed by pair wise comparison using post hoc test. Comparison of frequencies of categories of variables with groups was done using chi square test.

There was a statistically significant difference seen for the frequencies between the groups ($p<0.05$), with higher no. of samples showing higher scores in HELIOSIT & ORTHOFIX, while higher no of samples showing lower scores in group ENLIGHT & TRANSBOND (Table 1). The descriptive statistics (mean and SD) of shear bond strength was measured for all the groups. The highest mean SBS was recorded in Transbond and least in Heliosit (Table 2). To find out the significant difference in the mean SBS among all Groups at a 95% confidence interval, the ANOVA test was done. It was evident that the mean shear bond strength recorded between different groups is highly significant (<0.001) as shown in (Table 3). Pairwise comparison between the groups was done by post-hoc tukey test. Tukey test revealed that the mean SBS were statistically highly significant ($p<0.001$) for Transbond Vs Enlight, Transbond Vs Orthofix, Enlight Vs Heliosit, Enlight Vs Orthofix. While a statistically non-significant difference ($p>0.05$) seen for Transbond Vs Enlight, Heliosit Vs Orthofix (Table 4).

4. Discussion

In the 1970s Orthodontic speciality witnessed a revolutionary change with the introduction and use of composite adhesives. Since the introduction of direct bonding of Orthodontic brackets, pumice prophylaxis has been a pre-requisite for achieving adequate enamel etching. There have been studies supporting the necessity of prophylactic cleaning for improved bond strength.[4] Scanning Electron Microscope studies have shown that pumice prophylaxis before acid treatment removes organic pellicle from the enamel surface which has been hypothesized to inhibit optimum etching from occurring.

The introduction of acid etching by *Buonocore*[4] in in 1955 has had far reaching effects on the attachments of orthodontic appliances to the teeth. *Buonocore* bonded acrylic resin to enamel surface that has been pre-treated with 85% phospshoric acid for 60 seconds. Light cured adhesives have become increasingly popular for bonding orthodontic attachments. By virtue of the materials "command set" it gives an increased working time with the adhesive unlike self-cure and allows the orthodontist to precisely position attachments. To further exploit these advantages newer adhesives have been introduced in the orthodontic armamentarium. Bonding orthodontic brackets to enamel is an exacting procedure that requires meticulous attention to preparation of bonding surface. Contamination with water, saliva or blood increases the incidence of bond failure.[6] Ultraviolet light cured material was introduced in the early 1970s which quickly replaced those that were self-cured. These ultra violet lights cured materials have disadvantages of radiation hazards and limited depth cure.

The problems overcame with the introduction of a blue, visible light cured composite resin. Compared with U-V light, visible light has a deeper curing capability. The clinical use of visible light-cured composite resin for direct bonding has gained wide acceptance. In the light cured resin, a single paste system consisting of ketones and amines as indicators. The ketone, Comphoroquinone is sensitive to blue light at 470 nm wavelength which catalyses the polymerisation reaction. The light source is a tungsten halogen light bulb. White light generated by the bulb when passed through a filter, removes infra-red and visible spectrum with wavelength greater than 500nm. In *1987 King et al.*[7] reported that tensile or shear bond strength of light cured resin (Heliosit,Heliosit-Ortho and Silix) was weaker than the tensile or the shear bond strength of self-cured resin (Concise and Right-on) with light exposure of 60, 40 or 20 seconds. In *1992 Wang and Meng*[8] found out that the tensile bond strength of light cured resin if Transbond was same as or even better than the bond strength of self cured resin of Concise. He also reported that visible light has the capacity to diffuse and to cure the visible light activated composite resin even under solid metal brackets. Forty second exposure time as suggested by King was employed in the study. With Heliosit and Transbond, the site of failure was more often associated with bracket base/composite interface as studied previously by *Bradburn*

Table 1: Distribution frequencies of ARI scores.

	ARI scores						
Groups	0	1	2	3	Total	Chi-Square value	P value of chi square test
Transbond	18	8	3	1	30		
Heliosit	8	10	5	7	30	19.975	0.018*
Orthofix	9	9	6	6	30		
Enlight	17	8	3	2	30		
Total	46	36	25	13	120		

* = statistically significant difference (p<0.05)
** = statistically highly significant difference (p<0.01)
# = non significant difference (p>0.05)

Table 2: Adhesive remanent index scores.

		ARI scores			
	Scores	0	1	2	3
Groups	Transbond	18	8	3	1
	Heliosit	8	10	5	7
	Enlight	17	8	3	2
	Orthofix	9	9	6	6

Table 3: Intergroup comparison of shear bond strength.

Adhesives	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Transbond	30	14.791000	5.8208610	1.0627390	5.9300	24.2400
Heliosit	30	6.710100	2.1645314	.3951876	3.0900	10.2510
Enlight	30	13.009000	3.5897184	.6553899	7.0400	19.3300
Orthofix	30	8.498000	1.7411023	.3178803	5.5800	11.2300
Total	120	10.752025	4.9065384	.4479036	3.0900	24.2400

Table 4: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1284.751	3	428.250	31.440	.000**
Within Groups	1580.069	116	13.621		
Total	2864.820	119			

Table 5: Pair wise comparison using post hoc test.

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.
Transbond	Heliosit	8.0809000*	.9529352	.000**
Transbond	Enlight	1.7820000	.9529352	.247#
Transbond	Orthofix	6.2930000*	.9529352	.000**
Heliosit	Enlight	-6.2989000*	.9529352	.000**
Heliosit	Orthofix	-1.7879000	.9529352	.244#
Enlight	Orthofix	4.5110000*	.9529352	.000**

There was a statistically highlysignificant difference seen for the values between the groups (p<0.01)
TransbondVs Enlight, Transbond Vs Orthofix, Enlight Vs Heliosit, Enlight Vs Orthofix
Whilea statistically non significant difference seen for the values between thegroups (p>0.05) as
TransbondVs Enlight, Heliosit Vs Orthofix

and Pender(1992).[9]

The equipment recommended to test bond strength is the Universal Testing Machine viz. Instron and Zwick, INTRON 3366 was used to test the shear bond strength of four different types of light cured adhesives.

In the current study, tests for the shear bond strength and ARI index of metal brackets using four different bonding systems: Transbond XT Light Cure Adhesive(3M UNITEK), Light cured Orthofix (Anabond Stedman Pharma Research (P) Ltd), Heliosit Orthodontic Bonding Material (IvoclarVivadent), Ormco Enlight Light Cure Adhesive, were performed. Upon testing the materials employed in this study, it was found that there is an increase in the shear bond strength value for Transbond when compared to others. Based on statistics, it was inferred that mean shear bond strength value for *Transbond XT* is higher than the mean values of *Enlight, Heliosit* and *Orthofix.* However all the adhesives tested had clinically acceptable Bond strength values. There was a statistically high significant difference seen for the values between the groups ($p<0.01$) with highest mean in group TRANSBOND & least in HELIOSIT.

The achievement of satisfactory bond strengths would depend on the presence of an unpolymerized surface layer that had not been affected by oxygen inhibition.

One of the finding of this study was the differing amount of residual debris on the tooth surface (ARI) obtained for the various bracket base / adhesive combination. The debonding characteristics for each specimen were determined with the Adhesive Remnant Index (ARI) developed by Artun and Bergland in 1984.[2] Debonded teeth were examined under Scanning Electron Microscope and a mean value was calculated for each group .When the data for adhesive debris were considered it was assumed that no excess adhesive was present beyond the margins of the bracket base. The result of the Chi-square (x^2) test that compares the sites of bond failure among the four variables indicated no statistical difference among the four groups($x^2 = 19.975$, $P = 0.018$).

The bond failure can occur at the enamel / adhesive or at the bracket base / adhesive interface. In the present study the mean ARI was recorded for all light cure adhesives and found less than half of the adhesive remained on the tooth surface, which showed that bond failure was more frequently observed at the bracket / adhesive interface. The reason for the fracture at the bracket / adhesive interface could be due to the filler size of the adhesive. While there are reports confirming that Transbond exhibits adhesive fracture because it is a microfilled adhesive, the particle size of other light cure material seems to be a proprietary secret. Since all the four adhesives tested in this study shows fracture at its bracket/ adhesive it is logical to assume that all of them are microfilled resin. In the current study since the bond failure was adhesive / bracket interface and less than half of the adhesive remained on the tooth surface, less amount of cleaning procedure required and the amount of enamel tear out and loss will be less. This finding is in accordance with the study done by *Bradburn and Pender,*[9] *Sinha and Nanda.*[10] Localised enamel tear outs have been reported to occur with debonding of both metal and ceramic brackets. It is likely that small filler particles may penetrate the etched enamel to a greater degree than macrofillers. Upon debonding the small fillers would reinforce the adhesive tags. The macrofiller, on the other hand, would create a more natural breakpoint in the enamel – adhesive interface. Similarly, with unfilled resins, there would be no natural breakpoint.

The most common debonding technique used are debonding pliers, hand scaler, green rubber wheels and other assorted rotary instrument attachment. Although some investigators have reported enamel loss during debonding several other have reported to the contrary. According to Pus and Way[11] 7.7 μm loss of enamel was measured following debonded of the unfilled adhesive with a hand instrument which differs significantly from the average 17.2 μm enamel loss associated with removal of the filled adhesive with rotary instrument. *Pus and Way (1980)* have shown that during orthodontic bracket removal, the enamel loss averaged 55.5 μm. Since the total thickness of enamel is 1500 to 2000 μm, the loss of 60 μm of enamel is clinically accepted.

Thus, Light cured adhesive has come to stay in Orthodontics with its unique property of command set. The findings of this study reveal that the bond strength observed in this study is adequate for clinical use. In general, the results of in vitro experiments are never precisely comparable with those of in vivo situations, since application-sensitive substrates and the complexity of the interactions involved are subject to error, and standardization can never succeed 100%. However, the results of in vitro experiments can provide important information for in vivo situations and are of decisive value for clinical practice and everyday clinical use.

5. Conclusion

This analytical study reveals that the mean shear bond strength of the Transbond was highest among the four adhesives studied. However, all the adhesives tested exhibits adequate bond strength for clinical use. ARI scores were nearly the same for Transbond and Enlight adhesives in the study.

Many factors that might affect intraoral bond strength are difficult to reproduce in the laboratory. Hence, in vitro studies give limited idea about the optimal bonding procedure. Further in vivo studies will be needed in order to obtain clinical confirmation of these promising results.

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None.

7. Conflict of Interest

None.

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