Original Article

Comparison of bonding characteristics of a newly introduced light cure adhesive system with conventional adhesive system

ABSTRACT

Background and Objectives: The purpose of this study was to investigate the effectiveness of newly introduced light cure adhesive system (eXact, TP Orthodontics) with respect to conventionally used adhesive system (Transbond XT, 3M Unitek) by comparing their shear bond strengths and Adhesive Remnant Index after subjecting to thermocycling.

Methods: Thirty human maxillary first premolars were divided into two groups. Group I (Experimental Group) was bonded with adhesive system eXact and Group II (Control Group) with Transbond XT. After thermocycling, shear bond strengths and adhesive remnants index were compared using SPSS Software. Independent-*t* test was used to compare the shear bond strength values and Chi-Square Test to compare ARI scores.

Results: The mean shear bond strength of the Group I and Group II were 9.60±1.41 MPa and 11.65± 2.07 MPa respectively. There was statistically significant difference between the two Groups ($P < 0.05$). The mean and (±SD) of ARI Scores of Group I and Group II were 2.80 ± 0.414 and 1.93 ± 0.594, respectively, which was statistically significant. The mean ARI score difference of the two adhesives were also statistically significant ($P < 0.05$).

Conclusion: The SBS of conventional light cure composite resin (Transbond XT, 3M Unitek) is comparatively higher than the new light-cure composite resin (eXact, TP Orthodontics); but eXact have SBS higher than the clinically acceptable values. ARI score value is higher for eXact as compared to Transbond XT.

Keywords: Light cure composite resin, thermocycling, shear bond strength, adhesive remnant index

INTRODUCTION

The introduction of acid etch technique by Buonocore[1] in 1955 heralded a new era in adhesive dentistry. A decade later Newman introduced the novel concept of bonding orthodontic attachments to tooth surfaces by means of epoxy adhesive.[2] Since then, various dental adhesives and methods of bonding orthodontic attachments have been developed. Rapid strides in adhesive dentistry advanced the orthodontic bonding technique concurrently and progressively.

Shear bond strength (SBS) is one of the critical factors to be considered in the evaluation of bonding materials. Reynolds[3] stated that bond strength of 5.9–7.8 MPa is sufficient to withstand masticatory forces. Bishara *et al*[4] observed 10.4 and 11.8 MPa of mean bond strength respectively with composite resin and conventional adhesive system. Another decisive factor affecting SBS is thermocycling, as thermal stresses in oral cavity can cause

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microstructural changes which could result in remarkable changes in physical properties of the adhesive material.[5] From the clinicians point of view, the removal of adhesive remnants from the enamel surface after debonding is an important factor. Adhesive Remnant Index (ARI) score was introduced by Årtun and Bergland (1984).[6] Later, Bishara and Trulove developed the 5-point scale to evaluate ARI Score.[7]

Very few studies have been conducted on the properties the newly available eXact adhesive. A comparison is needed in terms of the SBS and ARI Score of this new adhesive and conventional orthodontic adhesives. Therefore, the purpose of this study was to investigate the effectiveness of newly introduced light cure adhesive eXact with respect to Transbond XT by comparing their SBS and ARI after subjecting to thermocycling.

MATERIALS AND METHODS

An *in vitro* experimental study to evaluate the SBS and debonding characteristics of eXact clear orthodontic adhesive (TP Orthodontics, Inc., La Porte, USA) and to compare it with that of conventionally used Transbond XT (3M Unitek). The study was conducted in the Department of Orthodontics, Government Dental College Trivandrum in collaboration with Sree Chithra Thirunal Institute of Medical Science and Biotechnology, Poojappura, Thiruvananthapuram. The institutional Ethics committee clearance was obtained.

In this study thirty healthy, human maxillary first premolar teeth, which were extracted for orthodontic treatment, were collected. All the extracted teeth were cleaned using coarse pumice with a rubber prophylaxis cup for 10s and rinsed with water. Each tooth was then embedded in a cylindrical colored acrylic block so that only the coronal portion of the specimen is exposed. The crowns were oriented along the long axis of the acrylic block. The specimens were stored in distilled water at room temperature in a closed airtight container. The samples were randomly divided into two groups – Group I and Group II. Bondable stainless steel 0.022” X 0.028” slot MBT premolar brackets (Ortho Organizer) were used. All brackets were of uniform size, and had a mesh base. The base of bracket had a surface area of approximately 14.9 mm^2. The bracket of samples in Group I were bonded using eXact clear orthodontic adhesive (TP Orthodontics, Inc., Laporte USA) [Figure 1]. The samples in Group II were bonded using Transbond XT Orthodontic adhesive (3M Unitek). The direct bonding protocol provided by the manufacturer was followed.

Bonding of samples in Group I

The enamel surfaces of the teeth were conditioned with TP Orthodontic blue etchant gel (37% phosphoric acid) using conventional acid etch technique for 30s, then thoroughly rinsed with distilled water and dried using oil free compressed air. Next, all the surfaces to be bonded were coated with bonding primer supplied with the kit. The mesh bases of the brackets were also coated with the primer. The new adhesive eXact was then applied onto the bracket base and bonding carried out as usual. Excess adhesive if any was removed from around the base of bracket and the adhesive was then light cured for 20 s with the help of light-emitting diode (LED) curing light [Figure 2].

Bonding of samples in Group II

The Group II samples were bonded with Transbond XT after etching with 37% Phosphoric acid and application of Transbond sealant. Excess adhesive was removed from around the base of the bracket and then light-cured for 20s with same LED curing light [Figure 3]. After bonding, the samples were stored for 24 hour in distilled water at room temperature in sealed plastic containers and labeled according to each group.

Thermocycling

The samples were then subjected to thermocycling in Wileytec Thermocycler machine applying 500 cycles at 5°C (±3°C) and 55°C (±3°C) temperatures. Each cycle was performed for 20s with 7-s intervals [Figure 4].

Method of shear bond strength evaluation

After a 48-h interval, counted from the end of thermocycling, the samples were subjected to SBS tests in the occluso-cervical direction and with the chisel positioned at the tooth-bracket interface.

The shear strength of bonded teeth was tested using an Instron

Figure 1: eXact adhesive system

Figure 2: Samples with brackets bonded using eXact

Figure 3: Samples with brackets bonded using Transbond XT

Figure 4: Samples in thermocycler

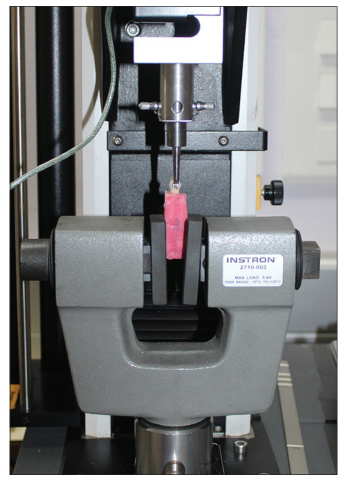

Figure 5: Shear bond strength testing in Universal Testing Machine

Universal Testing Machine (UTM) Model No: 3345 [Figure 5]. The sample testing was carried out using a sensitive load cell value of 5000 Newton. This technique of testing SBS has been widely reported in the literature. The testing external environment recorded 50% humidity and room temperature was 25°C. Each tooth was oriented with the testing device as a guide and held firmly between the lower cross head of the UTM, so that its labial surface would be parallel to the applied force during the SBS tests. A gingivo-occlusal load that produced a shear force at the bracket-tooth interface was applied to the bracket. The results of each test were recorded in Newton (N) on a graphic plotter. SBSs were measured at a crosshead speed of 0.5 mm/min. The result of each tests was recorded recorded in Newton (N) and then converted to Megapascals (MPa = N/mm^2) as follows:

$$\text{Load in Megapascal} = \frac{\text{Load in Newton}}{\text{Bracket base area in mm}^2}$$

The conversion was made to allow for comparison with other studies.

Determination of remaining residual adhesive after debonding

The amount of adhesive remaining on tooth surface is evaluated by ARI proposed by Artun and Bergland. Each tooth is examined under stereomicroscope, after debonding the brackets and are scored as:

- 0 – No composite left on enamel surface
- 1 – Less than half of composite left on enamel surface
- 2 – More than half of composite left on enamel surface
- 3 – All composite left on enamel surface.

RESULTS

Shear bond strength comparison

The mean and standard deviation (±SD) of SBS values of experimental group (Group I) and control group (Group II) were 9.60 ± 1.41 Megapascal and 11.65 ± 2.07 Megapascal respectively. Independent *t*-test was carried out to find whether there was any statistically significant difference between the two groups. The data obtained revealed that there was statistically significant difference between the Group I and Group II ($P < 0.05$) [Tables 1 and 2].

Table 1: Mean and standard deviations for shear bond strength values of the two groups in Mega Pascals

Descriptive statistics						
Group	Statistic			Mean		SD
	n	Minimum	Maximum	Statistic	SE	Statistic
Group 1						
SBS	15	6.19231	11.54410	9.6014920	0.36332159	1.40713847
Valid N (listwise)	15					
Group 2						
SBS	15	6.95095	13.79570	11.6519360	0.53409775	2.06855170
Valid N (listwise)	15					

SBS: Shear bond strength, SE: Standard error, SD: Standard deviation

Adhesive remnant index score comparison

The mean and (±SD) of ARI Scores of Group I and Group II were 2.80 ± 0.414 and 1.93 ± 0.594, respectively. Pearson Chi-square test was done to find out whether there was any statistically significant difference between the ARI scores of Group I and Group II. The Chi-square value obtained was 13.912 with a $P = 0.001$. The data obtained revealed that there was statistically significant difference between the ARI scores of Group I and Group II ($P < 0.05$) [Table 3].

Table 2: Independent *t*-test for comparing the shear bond strength values of the two groups

	Mean difference	Standard error difference	Significant
Shear bond strength	−2.050	0.646	0.004

Table 3: Chi-square test for comparing adhesive remnant index scores

Chi-square tests			
	Value	df	Asymptotic significance (two-sided)
Pearson Chi-square	13.912	2	0.001
Likelihood ratio	16.060	2	0.000
Linear-by-linear association	12.599	1	0.000
Number of valid cases	30		

DISCUSSION

Manufacturers have continuously introduced new adhesives that are claimed to be more reliable, i.e., stronger, adhere better, and or easier to handle. As new adhesives and bonding techniques are introduced, orthodontists adopt some of these innovations and add them to their armamentarium. eXact Clear Orthodontic Adhesive was brought to the market in 2015 by TP Orthodontics, Inc., La Porte, Indiana, USA. In this study, SBS and ARI score of eXact was compared with conventionally used Transbond XT.

The most commonly used artificial ageing technique is long-term water storage. Another widely used ageing technique is thermocycling. The International Organization for Standardization (ISO) TR 11450 standard (1994)[8] indicates that a thermocycling regimen comprising 500 cycles in water between 5°C and 55°C is an appropriate artificial ageing test, and many studies have been carried out following this ISO stantard. The Present study is done according to these specifications. However, according to the study reports of Gale and Darvell,[9] this number of cycles is probably too low to achieve a realistic ageing effect. They recommend 35°C (28 s), 15°C (2 s), 35°C (28 s), 45°C (2 s), and 10,000 cycles.

The bond strength of adhesive and attachments should be sufficient to withstand the forces of mastication, the stresses exerted by the archwires, and patient abuse as well as allow for control of tooth movement in all three planes of space. At the same time, the bond strength should be at a level to allow for bracket debonding without causing damage to the enamel surface. Bonded brackets are subjected to a combination of tensile, shear, and torsion forces during orthodontic treatment. It is difficult to measure and quantify these forces precisely. SBS resists the forces of occlusion acting on the bonded attachments. Both shear and tensile loading modes are valid tests for studying orthodontic bonding. In the present study, SBS was chosen as the parameter to be tested as it most closely represents the clinical situation.[10]

In vitro bond strength measurements are often used in the orthodontic literature to evaluate and compare new products. Inconsistency in methodology among studies makes it difficult to compare results. In this study, a standardized bonding protocol as proposed by Fox *et al*.[11] was followed. All bonding were done in dry field and the bonded specimens were stored in distilled water for 24 h for attaining the maximum the bond strength.[12] An occlusogingival load was applied to the bracket – adhesive interface using a 0.6 mm chisel blade at 0.5 mm/min crosshead speed.

The mean SBS of adhesive eXact in Group I was found to be 9.60 ± 1.41 MPa. Whereas the mean SBS of uncoated ceramic bracket bonded with Turbo bond was found to be 11.65 ± 2.07 MPa. The brackets in Group I bonded with eXact showed statistically significant lesser bond strength value compared to Group II bonded with Transbond XT in this study. Retief showed that enamel fractures could occur with SBS values as low as 13.53 MPa.[13] It was reported that clinically adequate SBSs for metal orthodontic brackets to enamel should range from 5.9 to 7.8 MPa in terms of clinical and 4.9 MPa in terms of laboratory performances as suggested by Reynolds.[14] The maximum bond strength for clinical use as recommended by Lopez[15] is 7 MPa. Although these values were suggested as adequate bond strength values for most clinical orthodontic needs, the minimum clinically acceptable SBS is not known. In the present study, the SBS was above these optimal values as suggested by Reynolds.

Among the various commercially available BisGMA-based resin Transbond XT has been extensively evaluated for its own bond strength as well as an adhesive to compare with other adhesives. Sharma *et al*.,[16] Tecco *et al*.[17] and and D'Attilio *et al*.[18] have reported very high values of 23.23 and 23.47 MPa for Transbond XT which is in contrast to the mean value of SBS obtained in this study.

According to the study by Murray and Hobson,[19] there was a significant difference between SBSs *in vivo* and in controls suggested that the generally used experimental environment of distilled water does not accurately simulate the oral environment. Since exposure to oral environment leads to biodegradation of the composites, which is the result of a combination of disintegration and dissolution in saliva, chemical and physical degradation, wear produced by mastication of food, erosion by food itself, and bacterial activity.

Of primary concern to the clinician is the maintenance of a sound, unblemished enamel surface after removal of the bracket, yet bracket failure at each of these two interfaces has its own advantages and disadvantages. As an example, bracket failure at the bracket/adhesive interface is advantageous because it leaves the enamel surface relatively intact. However, considerable chair time is needed to remove the residual adhesive, with the added possibility of damaging the enamel surface during the cleaning process. Bond failure at the enamel surface can cause enamel fractures; it occurs when the bond between bracket and adhesive is excessively strong.

The present study evaluates ARI score using the method proposed by Artun and Bergland.[6] In this method the amount of adhesive remaining on the tooth surfaces is taken into account. This ARI score provided an assessment of failure site characteristics and is necessary for any bonding study. Many bond strength studies evaluated ARI scores as proposed by Bishara *et al*.,[4] in which the scoring was done in a different gradation pattern as the amount of adhesive left on bracket base. ARI assessment in the present study yields only a qualitative value. Quantitative measurement of residual adhesive can be evaluated using digital photographs/scanning electron micrographs/high-precision elemental maps of the adhesive remnant as determined by energy dispersed X-ray spectrometry. According to Cehreli *et al*.[20] qualitative visual scoring using the ARI is capable of generating similar results with those assessed by quantitative image analysis techniques.

The present study obtained mean ARI Scores of Group I and Group II were 2.80 ± 0.414 and 1.93 ± 0.594, respectively. As reflected by the ARI scores with mean value being 2.80 ± 0.414, comparably more resin remnant was left on the enamel surface with the brackets bonded with eXact (Group 1). A higher ARI score would seem to be more desirable to minimize the enamel fractures. The mean value for the ARI scores of the brackets bonded with Transbond XT being 1.93 ± 0.594 implies that comparably more enamel fractures and damage tend to increase in this score. Thus, although this adhesive can provide more stable bonding between the bracket and a tooth, it may not be optimal in terms of enamel damage. Conversely, the clinician would have to spend very little time removing the adhesive from the tooth. According to O'Brien *et al*.,[21] the amount of residual debris following removal of the bonded bracket was not related to the SBS at the separate interfaces but was related to bracket base design and properties of the adhesive used.

Ideal ARI score is a subject of debate. Proponents of low score of modified ARI (score 1 and 2) claim that the tooth surface requires extensive cleaning of already damaged etched enamel surface.[22] Group II had more percentage of score 1 and 2 compare with that of groups I with more percentage of score 2 and 3.

Proponents of high score of modified ARI claims that there is a possibility of enamel crack or tear since entire adhesive comes out with bracket base. Group I showed increased frequency of score 3 compared to Group II. It is suggested that bond failure at bracket adhesive interface is more desirable than adhesive enamel interface, because enamel fracture and cracking have been reported, though inherent weakness of the tooth surface can also cause tooth fracture.

The adhesive failure noted in the present study is favorable and indicates moderate amount of bond strength at clinically acceptable level, and facilitate easy debonding after treatment. Further, it requires more clean up time; which is a drawback as far as the time taken is concerned. Since less force is generated damage during debonding is minimal. The above discussion on the present study reveals that eXact has slightly lower bond strength values with that of Transbond XT. However, the SBS values of this new adhesive is within the clinically acceptable levels.

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.

CONCLUSION

The present study was an *in vitro* study designed to test the SBS and estimation of ARI score of orthodontic brackets bonded to enamel using light cure composite resin (eXact, TP Orthodontics) and conventional light cure composite resin (Transbond XT, 3M Unitek).

The following conclusions can be drawn from the study:

- The SBS of light cure composite resin (Transbond XT, 3M Unitek) is comparatively higher than the new light-cure composite resin (eXact, TP Orthodontics); but eXact have SBS higher than the clinically acceptable values.
- ARI score value is higher for eXact (TP Orthodontics) compared to Transbond XT (3M Unitek).

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Conflicts of interest
There are no conflicts of interest.

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