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Comparison of Shear Bond Strength and Adhesive Remnant Index of Two Different Orthodontic Bonding Adhesives: An In-Vitro Study

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ABSTRACT

Aim: The purpose of this in vitro study was to determine and compare the shear bond strength (SBS)and adhesive remnant index scores (ARI) of stainless-steel brackets bonded with two different orthodontic bonding adhesive systems.

Material and Methods: Human premolar teeth(n=40) extracted for orthodontic reasons were randomly assigned to two groups and bonded using assigned protocols. Group 1(n=20) was Transbond XT Light Cure Adhesive (3M, USA), Group 2(n=20) was FUSION CRYSTA ADHESIVE (PREVEST DenPro). SBS was measured using a universal testing machine. ARI was evaluated after debonding via stereomicroscopy.

Results: The mean SBSs in MPa for two groups were respectively 2.29(+-0.68) MPa and 5.35(+-1.59) MPa. The difference in shear bond strength between two products was statistically significant ($p<0.05$). There was significant difference observed in ARI of Transbond XT and Fusion Crysta groups ($P<0.05$). For Fusion Crysta, 60% teeth had ARI score of 3, 30% had a score of 2, and 10% had a score of 1. For Transbond XT, 30% of the teeth had ARI score of 0, another 30% had a score of 1, 10% had a score of 2, and 30% had a score of 3.

Conclusion: Results of the in vitro study suggest that Fusion Crysta exhibits significantly greater shear bond strength compared to Transbond XT, suggesting its superior bonding capabilities. Transbond XT had less adhesive left on the tooth surface compared to Fusion Crysta. Fusion Crysta may be more consistent in leaving adhesive on the tooth after bracket removal, which could be disadvantageous depending on the clinical situation.

Introduction: The direct bonding of orthodontic brackets to teeth was made possible by Bunocore's invention of the acid etching technology in 1995 (1). This approach is now an essential component of orthodontics and the method has been improved over time, with modifications documented when new methods or resources become accessible. Patients are not only concerned about their smile, but also about the materials used during the treatment (2). Increasing expectations in the field of aesthetics have also changed the treatment strategies which are preferred in orthodontics and have led to the development of many innovations. More recently, bonding brackets has become more straightforward, predictable, and efficient due to developments in bonding materials and techniques. (3) In the bracket and adhesive-tooth interface, the adhesive system is crucial. An adhesive needs to withstand a variety of harmful circumstances found in the oral cavity, including persistent dampness, a moderately warm environment, and difficult-to-remove adherent contaminants. It must also be able to tolerate a significant amount of applied orthodontic stress in addition to masticatory stress. (4)

Bond strength is commonly used to compare the performance of different adhesive systems, and Reynolds et al has suggested values of 5.9 to 7.8 MPa (60-80 kg/cm^2) to be an appropriate minimum strength for orthodontic brackets (5), although it has been supported that bond strengths of even higher magnitude may cause brackets to fail prematurely (6). Light activated composites have a higher initial bond strength enabling immediate placement of archwires. There is a wide variation in methods and results of shear bond strength tests in the literature. Besides the bonding material used and the enamel surface preparation, the type of bracket and its base design also influences the bond strength. (7)

A˚rtun and Bergland used an Adhesive Remnant Index (ARI) system to evaluate the amount of adhesive left on the tooth after debracketing. This index system was developed on the basis of a pilot study of 20 extracted teeth and has four scores. Over the years, ARI scores have been one of the most frequently evaluated aspects in studies on orthodontic adhesives (8). Because the adhesive remnant score system is qualitative and subjective, many attempts have been made to modify the original system, or to develop new quantitative methods that can be used to more accurately assess the adhesive remnant (9). To more accurately evaluate the adhesive remnant

qualitatively, many studies expanded the ARI system that was developed by A˚rtun and Bergland into 5 or 6 scales (10, 11). To accurately score the ARI is important because it is an important factor to be considered in the selection of orthodontic adhesive. Accurate evaluation of the adhesive remnant, which is crucial in the final process of enamel cleaning after debonding, is needed for satisfactory removal and restoration of the enamel surface to as close to pretreatment condition as possible.

Transbond XT is a widely used, established Bis-GMA–based light-cured adhesive for orthodontic bonding. A newer, more cost-effective material, FUSION CRYSTA ADHESIVE, has recently been introduced, but its effectiveness has not yet been scientifically assessed. Therefore, this study aimed to compare the shear bond strength (SBS) and Adhesive Remnant Index (ARI) scores of brackets bonded with Transbond XT and FUSION CRYSTA ADHESIVE under in-vitro conditions.

Material and Methods: In this study, 40 extracted premolar teeth for orthodontic purpose were used and stored after in distilled water, changed two times in a week. The inclusion criteria were intact tooth walls, no caries or fracture lines or abnormal wear. Test groups were created by randomly selecting teeth without fractures and /or cracks among the collected teeth to be included in 2 separate bond groups. each group containing 20 teeth. Group 1- Transbond XT (3M Unitek) and Group 2- FUSION CRYSTA ADHESIVE (PREVEST DenPro). To help in the testing, the roots of each premolar were embedded in 20mm X 25mm blocks of cold cure acrylic so as to prevent any displacement of teeth during shear bond strength testing. with only the buccal surface of the crown exposed and oriented parallel to the bottom of the mould so that the labial surface would be parallel to the applied force during the shear test.All teeth were thoroughly cleaned and polishing was done with pumice and rubber prophylactic cups for 10s. Enamel surfaces were applied 37% phosphoric acid etch agent, rinsed and dried thoroughly with moisture and oil-free air to obtain an opaque white appearance. Premolar stainless-steel brackets (3M Unitek Gemini Metal Brackets) were bonded to the specimens with Transbond XT light cure adhesive and FUSION CRYSTA ADHESIVE (PREVEST DenPro), in keeping with the manufacturer's instructions of the two different bonding systems. All teeth were prepared and bonded by the same operator (Fig 1)

Twenty-four hours after bonding, shear bond strength test of all specimens was performed using a Universal Testing

Machine (UNITEST 10, ACME Engineers, India) with a System Accuracy of the machine ± 1%. occlusogingival load was applied at bracket base-resin interface with a crosshead speed of 1mm/minute. All specimens were tested by the same operator. SBS and the maximum load required to debond the brackets from the teeth was determined. The results of each test were given in MPa for SBS and N for maximum load and recorded by a computer that was connected to the testing machine. Area of bracket was determined to be 14.014 mm^2. After debonding, the enamel surface of each tooth was examined and the Adhesive Remnant Index (ARI) was determined using a stereomicroscope. All teeth were analysed by the same observer. The ARI, as proposed by Artün and Bergland,(8) was used to classify the enamel surface after debonding, according to the following scores: score 0, no composite resin left on the tooth surface implying that bond fracture occurred at the resin/enamel interface; 1 indicates that less than half the adhesive is left on the tooth surface, implying that bond fracture occurred predominantly at the resin/enamel interface; 2 indicates that more than half the adhesive is left on the tooth surface, implying that bond fracture occurred predominantly at the bracket/resin interface; and 3 indicates that all adhesive is left on the tooth surface with a distinct impression of the bracket base, implying that bond fracture occurred at the bracket/resin interface. The protocol of this study was revised and approved by the Department of Orthodontics and Dentofacial Orthopaedics, India and by Institutional Ethical Committee and Review Boards.

Statistical Analysis: The data obtained from the study was tabulated. The level of significance was set at 5% (0.05), and the power of the study was 80% using the G power software. The mean and standard deviation was calculated for both the groups to get the arithmetic average of the observations. Unpaired t-test was carried out for comparison between two groups. The chi-square test was performed to compare the distribution of ARI scores between the two groups.

Fig. 1 Premolar teeth mounted in acrylic blocks for testing

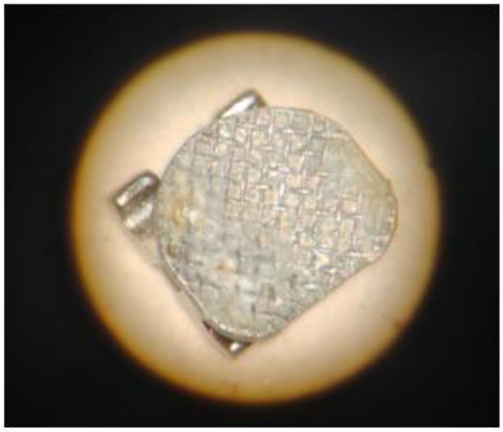

Fig. 2 Adhesive Remnants as seen under microscope

Results: Mean values of Maximum load for Transbond XT was 32.01N+- 9.62N and for Fusion Crysta it was 71.95N+-25.97N. (Table 1) Unpaired t-test was carried out for comparison between two groups. P-Value is less than 0.05. Hence, we can conclude that, there is significant difference observed in max load in Transbond XT (32.01N+-9.62N) and Fusion Crysta. (71.95N+-25.97N) Further, mean value observed in Fusin Crysta group is greater than Transbond XT. Fusion Crysta significantly outperforms Transbond XT in terms of max load, as evidenced by a higher mean value and a significant p-value.

Mean values of SBS for each Group are listed in Table 2 On average, shear bond strength is 2.29MPa(+-0.68MPa) for Transbond XT and 5.35MPa (+-1.59MPa) for Fusion Crysta. Unpaired t-test was

carried out for comparison between two groups. P-Value is less than 0.05. Hence, we can conclude that, there is significant difference observed in SBS of Transbond XT and Fusion Crysta. Further, mean value observed in Fusion Crysta group is greater than Transbond XT, suggesting it has superior bonding capabilities.

For Fusion Crysta, 60% (n=12) of the teeth had an ARI score of 3 (all adhesive left on the tooth), 30% (n=6) had a score of 2, and 10% (n=2) had a score of 1. For Transbond XT, 30% (n=6) of the teeth had an ARI score of 0 (no adhesive left on the tooth), another 30% (n=6) had a score of 1, 10% (n=2) had a score of 2, and 30% (n=6) had a score of 3. The chi-square test was performed to compare the distribution of ARI scores between the two groups, and the p-value (0.007383) was less than 0.05, indicating a statistically significant difference in the distribution of ARI scores between Transbond XT and Fusion Crysta. Fusion Crysta shows a higher tendency to leave adhesive on the teeth, with 60% of cases showing all adhesive left on the tooth (score 3), and no cases where no adhesive was left (score 0). Transbond XT, in contrast, shows a more balanced distribution across all scores, with 30% of cases for each score (0, 1, 2, and 3), indicating a variability in the amount of adhesive left after bracket removal (Fig. 2). This analysis suggests that Fusion Crysta may be more consistent in leaving adhesive on the tooth after bracket removal, which could be advantageous or disadvantageous depending on the clinical situation. The significant p-value in both the Mann-Whitney U test and the chi-square test indicates that these findings are statistically significant and not likely due to chance

The table 4 presents the results of a Mann-Whitney U test, which is a non-parametric test used to compare two independent groups when the data is ordinal (ranked). In this case, the test was used to compare the ARI scores between two groups: Fusion Crysta and Transbond XT. The table shows the following results: The mean rank for Fusion Crysta was 13.00, and the sum of ranks was 260.00. The mean rank for Transbond XT was 8.00, and the sum of ranks was 160.00. The p-value (0.045) is less than 0.05, indicating a statistically significant difference in the ARI scores between Fusion Crysta and Transbond XT. The interpretation provided in the table states that the gradations (ARI scores) observed in the Transbond XT group were lower than those in the Fusion Crysta group. This means that Transbond XT had less adhesive left on the tooth surface compared to Fusion Crysta.

Table 1: Comparison of maximum load for Transbond XT and Fusion Crysta Adhesive

Max Load	N	Mean	SD	SE	t-Value	P-Value	Result
Transbond XT	20	32.01	9.62	3.04	-4.560	0.000243	Sig
Fusion Crysta	20	71.95	25.97	8.21			

Table 2: Comparison of SBS for Transbond XT and Fusion Crysta Adhesive

Shear Bond Strength	N	Mean	SD	SE	t-Value	P-Value	Result
Transbond XT	20	2.29	0.68	0.21	-5.616	0.000025	Sig
Fusion Crysta	20	5.35	1.59	0.50			

Table 3: Shows the distribution of ARI scores for both groups

	ARI Score (%) and number of teeth (n)			
	0	1	2	3
Fusion Crysta	0 (n=0)	10 (n=2)	30 (n=6)	60 (n=12)
Transbond XT	30 (n=6)	30 (n=6)	10 (n=2)	30 (n=6)

Table 4: Mann Whitney U Test carried out for comparison of ARI scores for Transbond XT and Fusion Crysta Adhesive

ARI	N	Mean Rank	Sum of Ranks	Mann-Whitney U	P-Value	Result
Fusion Crysta	20	13.00	260.00	25.000	0.045	Sig
Transbond XT	20	8.00	160.00			

Discussion: Shear is defined as "A strain in the structure of a substance produced by pressure when its layers are laterally shifted in relation to each other." (12). A majority of studies regarding orthodontic bond strength use 'shear' bond strength rather

than peel, tension, torsion, or cleavage because it is the most reproducible. It is important to note, however, that the shear bond strength can be very significantly affected based on the location of the blade applying the force during debond. Ideally, the blade of the debonding instrument should be placed at the bracket base where it meets the tooth enamel (13). The entire bracket-based layer is being shifted evenly in this manner. in relation to the enamel surface laterally. Today's composite resins include inert fillers like silica and monomers of resin. The resin can be cured and polymerized by light, chemical, or both (14). A light cured resin is convenient because no mixing is required and it has better initial properties. Proffit defines a successful bonding material as dimensionally stable, fluid enough to penetrate enamel, strong, and easy to use. Clinically the majority of the adhesion is regulated by micromechanical retention however, mechanical retention is required within the metal bracket base (15).

Ideally, the bond strength should be optimal rather than excessive or inadequate. excessive bonding force exacerbates the possibility of enamel damage during debonding, and a bond strength that is too low leads to frequent bonding failures in the treatment process. According to Reynolds et al the optimum bond strength should be in the range of 6 to 8 MPa. Bond strengths over 10 MPa have been associated with enlarged risk of enamel fracture during debonding (5). In our study Fusion Crysta exhibited significantly greater shear bond strength 5.35MPa (+-1.59MPa) compared to Transbond XT 2.29MPa(+-0.68MPa), suggesting it has superior bonding capabilities. The results for SBS of Transbond XT in this in vitro study are not similar to those that have been previously reported in literature in similar studies by Junaid et al (16), Ersa et al (17), who found the SBS to be in the range of 7MPa – 9MPa. Whereas, Sudhir et al (18), Bhogi et al (19), S Shaalini et al (20), reported the SBS to be in the range of 15MPa- 18 MPa.

It must be considered that the risk of enamel fracture is not exclusively dictated by bond strength; since surface conditioning and debonding techniques can also have great influence. Finnema et al observed, throughout a meta-analysis, that higher curing time leads to stronger bond strength. The authors found that each additional second of light-curing increased in vitro bond strength by 0.077 MPa, but they were not able to find the optimal curing time for bonding (21). A curing time of 20 seconds adopted in the present study was determined by the manufacturer of both the bonding systems.It has been suggested that larger bracket bases provide stronger bond

strength, although this factor was not considered in this study as all the brackets used were upper premolar brackets from the same manufacturer having the same base area.

The ARI scoring has proven to be valuable in research on orthodontic adhesive systems. It is a convenient and straightforward method and does not require any specialized equipment. Throughout the years, ARI scores have been extensively examined in studies on orthodontic adhesives. Accurate scoring of the ARI is crucial as it plays a significant role in the selection of orthodontic adhesive. The variations in ARI scores indicate differences in strength of bond between the enamel and the resin for various adhesives. However, adhesives that exhibit minimal remnant on the surface have been recommended. Precise evaluation of the remnant is essential in the final stages of polishing post treatment, ensuring proper removal and restoration of the enamel to its pre-treatment condition as closely as possible. In our study, Fusion Crysta shows a higher tendency to leave adhesive on the teeth, with 60% of cases showing all adhesive left on the tooth (score 3), and no cases where no adhesive was left (score 0). Transbond XT, in contrast, shows a more balanced distribution across all scores, with 30% of cases for each score (0, 1, and 3), indicating a variability in the amount of adhesive left after bracket removal. This finding corroborates with the findings of Andreas Hellak et al (22), Nishtha Arora et al (23) and Sachin T et al (24), who found the ARI of Transbond XT to be evenly distributed in the range of 0-2. The analysis suggests that Fusion Crysta may be more consistent in leaving adhesive on the tooth after bracket removal. Low ARI scores (0 and 1) have been considered favourable by some authors, since there is less adhesive to remove from the tooth surface and, thus, less risk of iatrogenic damage during enamel polishing. Studies have been conducted over this matter, since the literature contains conflicting reports of whether low ARI scores are desirable or not.

Studies have shown a direct correlation between (ARI) and SBS. Two categories of failures are discussed: adhesive type, which refers to failure that occurs between 2 interfaces, and cohesive type of failure, which refers to failure occurring within the adhesive itself (25). In our study it was found that in Fusion Crysta group 60% of the samples showed ARI score 3, implying that bond fracture occurred at the bracket/resin interface. Whereas for Transbond XT group, equal fractures were seen at the resin/enamel interface,

predominantly at the resin/enamel interface and at the bracket/resin interface.

Limitations: In order to obtain clinically relevant results from in vitro studies, precise simulation of the clinical condition is required. However, this is a difficult and unrealistic goal, considering that many factors are associated in vivo and the majority of studies over dental adhesives remain in vitro. This study only tested stainless steel brackets, and the results cannot be extended to other types of material, such as ceramic brackets, other types of adhesives, different enamel preparations or bonding on different surfaces, such as restorative material. In this study, the ARI was determined using a stereomicroscope, however a scanning electron microscope study to evaluate the depth of penetration of the adhesive resin into the enamel surface would be a better and more accurate method to evaluate the amount of bonding adhesive left on the tooth surface.

Conclusion:

1. SBSs of both adhesives and ARI score distributions presented with significant differences when used to bond stainless steel orthodontic brackets, wherein Fusion Crysta exhibited significantly greater shear bond strength compared to Transbond XT
2. Fusion Crysta shows a higher tendency to leave adhesive on the tooth surface compared to Transbond XT.

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