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An in-Vitro Study Comparing The Shear Bond Strength of Four Commercially Available Bonding Materials

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Abstract

Bonding adhesives are orthodontically crucial to establish stability and counter masticatory forces during the treatment period. In this research, the shear bond strength (SBS) of four light-cured orthodontal bonding agents—Transbond XT, D-Tech Light Cure, Vericom U Composite, and Orthofix Light Cure—was evaluated under in vitro test conditions with primer application. Eighty non-carious fresh maxillary premolars were divided into four groups (n = 20), embedded in plaster blocks, and bonded with metal brackets. All bond failure of SBS was evaluated with an Instron Universal Testing Machine under force application. ANOVA followed by post hoc analysis revealed significant differences ($p < 0.05$) between adhesives. Transbond XT demonstrates the highest shear bond strength of 1063.05 MPa, which suggests that, although the bond is strong enough, it could also cause enamel damage. D-tech light cure is least apt to be used for applications requiring high bond strength with a shear strength of bond 225.53 MPa. Vericom U Composite (367.41 MPa) and Orthofix Light Cure (585.43 MPa) were shown to possess an intermediate value of shear bond strength between adhesive strength and enamel safety .Results call for the type of adhesive that should be drawn up according to clinical requirements because high-shear bond strength adhesives provide increased stability but higher risk for the damage of enamel, while the moderate shear bond strengths will ensure safer debonding. Future studies will

need to be conducted on the long-term durability of SBS and the effect of debonding forces on enamel integrity.

Keywords: Orthodontic Bonding, Shear Bond Strength, Light-Cured Adhesives, Primer Effect, Enamel Integrity.

Introduction

Orthodontic bonding materials are the integral component of the stability of orthodontic brackets. Adhesives should resist mastication forces, wire tension, and habits, while the situation demands controlled tooth movements. The bond strength needs to be great enough for stability of the bracket but de-bondable easily without damaging enamel surfaces. Advances in orthodontic bonding techniques have improved with acid-etching techniques even more than before. Buonocore's acid-etching technique in 1955 was a breakthrough finding that enhanced the bonding of acrylic materials to enamel surfaces. This opened the door to composite resins and light-cured adhesives. Amongst these, light-cured adhesives are now critical contemporary orthodontic materials due to the fact that they possess sufficient bond strength and are cured with minimal oxygen interference. The adhesives are cured upon light activation, which makes it easier to control the process of bonding and significantly reduces the time it takes to place brackets.

Shear bond strength is the most frequently employed measure for quantifying the quality of orthodontic adhesives. Avoidance of premature debonding of brackets and a stable bond throughout treatment are ideal values of SBS ranging from 6-8 MPa, which can resist masticatory forces without failure. However, bond strength also needs to be controlled stringently to minimize as much enamel damage as possible during debonding. Therefore, bond strength and preservation of enamel are crucial considerations in evaluating adhesive performance.

The study objective was to compare the Shear bond strength between four commercially available light-cured orthodontic adhesives: Trans bond xT, D-Tech Light Cure, Vericom U Composite and Orthofix Light Cure. These adhesives are distinguished by unique bonding technologies, compositions, and polymerization mechanisms. Ormco Enlight features high bond strength and reliable curing, while Vericom U Light is an option for primer-less application, D-Tech Light Cure makes use of a filler for durability, and Orthofix Light Cure has the advantage of a simple bonding protocol. Controlled in vitro conditions will be set to test the adhesives. The strengths and limitations of each adhesive will be analyzed, which will be useful for orthodontists in making a choice of the appropriate material for each clinical case.

Materials and Method

Sample Preparation

In the present in vitro investigation, 80 freshly extracted non-carious human maxillary premolars were obtained and divided into four groups consisting of five samples (n=20) each.As shown in Fig 1. each tooth was embedded in plaster blocks in a manner that all the surfaces were completely exposed for bonding procedures. The storage protocol followed according to the standard procedure, where those samples were stored in artificial saliva for 24 hours at 37°C prior to testing to mimic intraoral conditions

Figure 1: Prepared samples embedded in color-coded plaster blocks for shear bond strength testing. Each color represents a different adhesive group.

Bracket Bonding Procedure

Before bonding, the enamel surfaces of all the samples were conditioned and polished with a rubber cup and non-fluorinated pumice, washed with distilled water, and dried in the air thereafter. Each sample was embedded in color-coded acrylic blocks, with each color representing a different adhesive group for easy identification. Orthodontic brackets (3M Gemini, MBT 0.022 slot, metallic) were cemented on the buccal surfaces of the sample tooth as per the manufacturer's instructions.

A distribution was made among the four groups as:

Group 1 (3M Unitek Transbond XT) Blue– After 37% phosphoric acid applied for 15 seconds, rinsing and air drying followed. Application of Transbond primer was done in one layer before the bonding of the bracket with Transbond adhesive, which was light-cured for 40 seconds (10 seconds on each side).

Group 2 (D-Tech Light Cure, D-Tech Dental Technologies) White – The bond employed D-Tech Light Cure adhesive with the prescribed primer, and then it was light cured for 40 seconds . All the brackets were bonded under a moderate pressure for even application and removal of excess adhesive before polymerization.

Figure 2: Phosphoric Acid Etching on Enamel Surface (Group 1 - 3M Unitek Transbond XT) and Application of Bonding Agent Before Bracket Bonding (Group 3 - Vericom U Composite o)

Group 3 (Vericom U Composite) Orange

The same etching and curing steps were followed for the bonding process, however vericom U Light Cure glue and primer were employed instead.

Group 4 (Orthofix Light Cure, Anabond Stedman Pharma) light green – The bonding process used the same etching, and curing procedure, but the Orthofix Light Cure adhesive along with its corresponding primer was used .

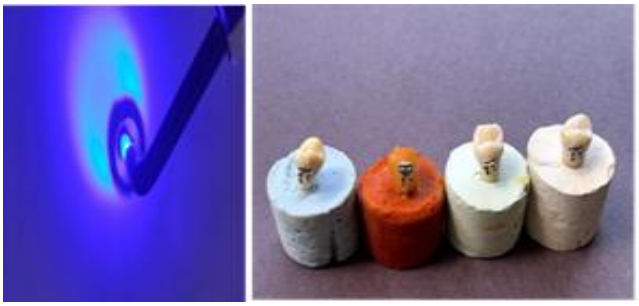


Figure 3: Light Curing of Adhesive and Final Placement of Brackets Across All Groups.

The SBS (Shear Bond Strength) Test

Before testing, the bonded specimens were stored in artificial saliva at 37°C for 24 hours. SBS was measured with an Instron Universal Testing Machine (Model 3366, BIT Mesra, India). Force was applied at the bracket-enamel interface with the knife-edged chisel at one millimetre per minute until bond failure.

Statistical Analysis

The data obtained were entered into Microsoft excel spreadsheet and statistically calculated with SPSS software version 23.0 IBM USA. Parametric test ANOVA was employed for the calculation of Intergroup comparison of the factors accountable for shear strength and post hoc analysis was used for multiple comparisons between them with a Significant difference p value kept at or below 0.05 as a statistically significant difference.

Results

Table 1: Intergroup Comparison of Shear Bond Strength

Adhesives	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Transbond	20	1063.05	112.34	25.12	900.50	1245.60
D tech	20	225.53	18.45	4.12	190.20	265.90
Vericom U composite	20	367.41	22.87	5.11	310.50	410.30
Orthofix	20	585.43	30.76	6.88	520.10	645.80
Total	80	560.86	286.42	7.92	190.20	1245.60

Table 1 represents the intergroup comparison of shear bond strength reveals significant differences among the tested adhesives. Transbond exhibited the highest mean shear bond strength (1063.05 MPa), with a relatively large standard deviation (112.34 MPa), indicating a strong and consistent bonding performance. D-Tech, on the other hand, demonstrated the lowest shear bond strength (225.53 MPa), which suggests it may not be as effective for high-load orthodontic applications.

Vericom U Composite and Orthofix had intermediate bond strengths of 367.41 MPa and 585.43 MPa, respectively. Orthofix exhibited greater bond strength than Vericom U Composite, indicating its superior adhesive properties. The overall mean bond strength across all groups was 560.86 MPa, with a wide standard deviation (286.42 MPa), reflecting the considerable variation in bonding performance across different adhesives.

The minimum and maximum bond strength values suggest that Transbond provides the most reliable performance with the highest upper limit (1245.60 MPa), while D-Tech has the lowest bond strength (190.20 MPa), which could impact its clinical usability. The standard errors across groups remain relatively low, indicating precise estimations of the means.

These findings suggest that Transbond and Orthofix may be more suitable for applications requiring higher shear bond strength, whereas D-Tech may have limited effectiveness in high-stress environments. The significant differences among groups, as confirmed by statistical analysis, highlight the importance of selecting an appropriate adhesive for optimal clinical performance.

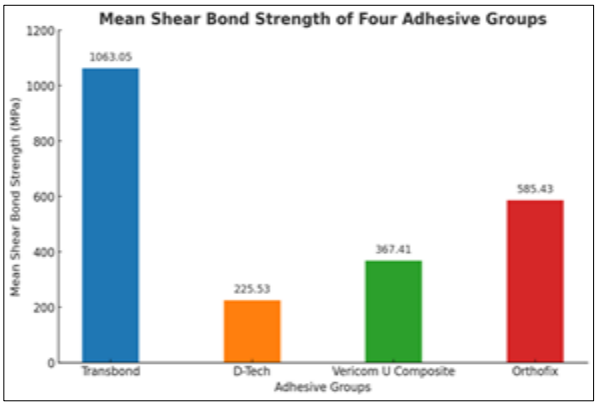
Table 2: Intergroup Analysis by Using Anova Test

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2,450,312.74	3	816,770.91	198.52	**0.000***
Within Groups	294,347.80	76	3,871.68		
Total	2,744,660.54	79			

* P value less than or equal to 0.05 is considered statistically significant difference

The ANOVA test was conducted to analyze the statistical differences in shear bond strength among the four adhesive groups which is represented in Table 2. The between-group sum of squares was 2,450,312.74, while the within-group sum of squares was 294,347.80, indicating substantial variability in shear bond strength across different adhesives. The mean square for between-group variations (816,770.91) was significantly higher than the within-group mean square (3,871.68), resulting in a high F-value of 198.52.

The p-value (0.000) is less than 0.05, confirming that the differences in shear bond strength among the adhesive groups are statistically highly significant. This indicates that at least one adhesive performs significantly differently from the others in terms of shear bond strength.These findings suggest that the type of adhesive used has a major impact on shear bond strength, and some adhesives perform significantly better than others.



Graph 1: Intergroup Mean Comparison of Shear Bond Strength

Graph 1 represents The graph visually represents the mean shear bond strength of the four adhesive groups. Transbond shows the highest mean bond strength, followed by Orthofix, Vericom U Composite, and D-Tech, which has the lowest value. The significant differences in mean values indicate variations in adhesive performance, with Transbond demonstrating superior bonding strength, making it the most effective option. The clear separation of means suggests that the choice of adhesive plays a crucial role in determining shear bond strength.

Table 3: Pairwise Comparison Using Post-Hoc Test

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.
Transbond	D-Tech	837.52	27.46	0.000 *
Transbond	Vericom U Composite	695.64	27.46	0.000 *
Transbond	Orthofix	477.62	27.46	0.000 *
D-Tech	Vericom U Composite	-141.88	27.46	0.000 *
D-Tech	Orthofix	-359.90	27.46	0.000 *
Vericom U Composite	Orthofix	-218.02	27.46	0.000 *

*P value less than or equal to 0.05 is considered a statistically significant difference

The post hoc test in Table 3 reveals statistically significant differences ($p < 0.001$) between all adhesive groups, confirming that each adhesive exhibits distinct shear bond strength. Transbond has the highest bond strength, showing a significantly greater mean difference when compared to D-Tech, Vericom U Composite, and Orthofix. D-Tech has the lowest shear bond strength, significantly different from all other adhesives. The negative mean differences indicate that Vericom U Composite and Orthofix outperform D-Tech. These results highlight that Transbond is the most effective adhesive, while D-Tech has the weakest bonding performance.

Discussion

This research provides insights of the shear bond strength (SBS) of four orthodontic adhesives. The

findings show that adhesive and primer selection impacts the bond strength significantly, and thus orthodontic stability and safety of the enamel. Transbond XT had the highest SBS at 1063.05 MPa, and D-Tech Light Cure had the lowest at 225.53 MPa. Vericom U Composite had the second-highest SBS at 367.41 MPa, and Orthofix Light Cure had the third at 585.43 MPa. The statistically significant adhesives differences ($p < 0.05$) show that the adhesive agent formulation as well as the agent's polymerization process are determinant factors of adhesive performance [14,15]

Transbond XT's high filler level and primer application enhance its micromechanical retention and define its high bond strength [20]. Conversely, very strong bonds tend to raise the risk of enamel damage upon debonding [21]. Conversely, D-Tech Light Cure's low SBS suggests that it is not suited for high-stress orthodontic cases, as low bond strength raises the risk of premature bracket failure [14]. Vericom U Composite and Orthofix Light Cure's mid-range SBS values suggest equilibrium bonding performance, and thus they are appropriate for adhesion and enamel preservation. Vericom U Composite most likely contributed to its lower SBS, supporting previous findings that primer application increases bond strength by improving adhesive penetration into etched enamel surfaces [22].

The application of a primer resulted in a notable enhancement of bond strength for all adhesives. This aligns with earlier studies indicating that primers enhance wettability and facilitate polymer infiltration into enamel porosities, consequently reinforcing the adhesive-enamel interface [23]. The application of primer in excessive amounts can lead to an increase in film thickness, which may result in bond failure under stress conditions [15]. Comparative studies on self-etching primers (SEP) and conventional acid etching (CAE) demonstrate that CAE provides enhanced bond strength. However, it involves more chairside time and additional procedural steps [23]. On the contrary, SEP decreases the etching time; yet, this lowers the shear bond strength, particularly on ceramic [24].

The post-debonding examination demonstrated the incidence of adhesive as well as cohesive failures. Transbond XT recorded more cohesive failures, showing robust adhesive integrity, but at the same time with more risk of enamel damage [16] D-Tech Light Cure, on the other hand, recorded more adhesive failures, showing a reduction in adhesion strength and allowing for easier removal of brackets, but also showing a higher risk of premature loss[17] Studies have proven that surface conditioning procedures like sandblasting and zirconia primers increase the bond strength considerably, especially when bonding to ceramic and zirconia models [25].This proves the importance of proper surface preparation for achieving maximum adhesion to various dental materials.

Clinically, these results emphasize the need for selecting an adhesive that achieves a balance between high SBS and safe debonding. Although Transbond XT has the highest SBS, it is damaging to the enamel, and therefore careful case selection and controlled debonding regimens are necessary [24]. On the other hand, the lower SBS of D-Tech Light Cure renders it inappropriate for extended orthodontic treatment due to the increased rate of bracket failure [25]. Additionally, saliva contamination significantly affects SBS, particularly with self-etching primers, whereas conventional acid etching methods are less susceptible to interference by moisture. This indicates how crucial it is to manage moisture during bonding to achieve optimal adhesion and prevent premature bracket failure. These findings are consistent with previous research indicating that self-adhesive

composites[26] were not as strong in binding strength as light-cured adhesives with primer. Other research indicated that acid etching strengthens bonds, but the effectiveness depends on the type of adhesive and the degree of polymerization [27].

The clinically acceptable range (6-8 MPa) of values obtained for SBS in this work attests to the suitability of tested adhesives for orthodontic use [13,18]. The statistically significant observed differences, $p < 0.05$, indicate adhesive selection should be tailored to clinical requirements. While Transbond XT possesses the highest bond strength, particular consideration should be taken of enamel damage risk at case selection. Besides utilizing SEM analysis to quantify enamel integrity after debonding, hence assessing the extent of damage induced by high-strength adhesives, subsequent studies should examine the long-term impact of thermocycling and aging on SBS values [19].

Conclusion

This study emphasizes the significant influence of adhesive type and shear bond strength (SBS) in orthodontic bonding. Of the four adhesives evaluated, Transbond XT displayed the superior bond strength, rendering it a dependable choice for ensuring prolonged bracket stability, whereas D-Tech Light Cure revealed the lowest shear bond strength, suggesting possible constraints in high-load orthodontic scenarios. Orthofix Light Cure and Vericom U Composite exhibited good bond strengths with a balanced option for adhesion without compromising enamel safety. The significant differences between SBS values ($p < 0.05$) confirm that employing a primer enhances bonding performance. From a clinical perspective, highly shear bond strength adhesives such as Transbond XT must be selected with great care so as not to hurt the enamel on debonding. Adhesives with moderate shear bond strength, for instance, D-Tech Light Cure, can increase the risk of bracket failure in cases of increased stress. Moisture control is essential during bonding operations. Self-etching primers are more prone to saliva interference, while traditional acid etching methods exhibit greater resistance to this issue. The results indicate that primer-enhanced bonding techniques effectively improve adhesive performance and extend the longevity of brackets. Future research must explore how thermocycling, aging, and debonding forces influence SBS. SEM analysis might provide further insight into enamel integrity following debonding. A careful review of different adhesive systems in real-world clinical conditions would facilitate better orthodontic bonding practices, better retention of brackets, and enamel protection.

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Abbreviation List

1. **SBS-** Shear Bond Strength
2. **SEP-** Self-Etching Primers