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RESEARCH ARTICLE

Comparative Evaluation of Shear Bond Strength of New and Rebonded Orthodontic Brackets Using Three Adhesive Systems: An In Vitro Study

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Abstract: ***Objective***: To evaluate and compare the shear bond strength (SBS) of new and rebonded orthodontic brackets using three different adhesive systems. ***Methods***: A total of 180 extracted premolars were randomly assigned to two groups (new and rebonded brackets) and further subdivided based on adhesive type (Transbond XT, Enlight, Blūgloo). SBS testing was performed using a universal testing machine, and statistical analysis was conducted using SPSS software. ***Results***: The mean SBS of new brackets (8.46 MPa) was significantly higher than that of rebonded brackets (7.45 MPa, p=0.001). Among new brackets, Transbond XT demonstrated the highest mean SBS (9.14 MPa), whereas among rebonded brackets, Enlight showed the highest (7.73 MPa). The only significant intergroup difference was between new Transbond XT and rebonded Blūgloo (p=0.026). ***Conclusion***: New brackets bonded with Transbond XT showed superior SBS compared to rebonded brackets. Rebonded adhesives demonstrated comparable SBS among themselves. Further studies are needed to optimize rebonding protocols.

Keywords: Shear bond strength, orthodontic brackets, adhesives, rebonding, Transbond XT, Blugloo, Enlight.

INTRODUCTION

"Strength does not come from physical capacity. It comes from an indomitable will." – Mahatma Gandhi

In orthodontics, the adhesive utilized must exhibit sufficient bond strength to endure normal orthodontic and masticatory forces while ensuring that it does not inflict damage to the enamel during debonding. Reynolds (1975) emphasized this balance, stating, "The adhesive used in orthodontics should possess sufficient bond strength to withstand normal orthodontic and masticatory forces, but not so high as to damage the enamel upon debonding." Similarly, Bishara et al. (2000) articulated that "an ideal orthodontic bonding agent must balance adequate shear bond strength with enamel protection during both treatment and debonding."

Shear bond strength (SBS) is defined as the maximum force an adhesive joint can withstand before failure occurs under a shearing force. An orthodontic adhesive is considered optimal when it demonstrates adequate bond strength, with Reynolds indicating that a bond strength range of 5.9 to 7.8 MPa is clinically sufficient to withstand functional masticatory forces. The significance of SBS in orthodontics is paramount, as it quantifies the adhesive bond between orthodontic brackets and the enamel surface of teeth. A sufficient bond strength is essential for maintaining bracket position and ensuring that intended tooth movements occur as planned. Inadequate bond strength can lead to bracket failure, necessitating rebonding procedures that prolong treatment duration and increase patient discomfort1.

Moreover, the bond strength must be balanced with the ability to remove brackets at the conclusion of treatment without causing enamel damage. Excessively high bond strengths can complicate debonding procedures, potentially resulting in enamel fractures or requiring extensive polishing to eliminate residual adhesive. Thus, achieving optimal SBS is critical for both treatment efficacy and the preservation of tooth structure2,3.

Several factors influence the shear bond strength of orthodontic adhesives. The type of adhesive plays a significant role, with resin-composite adhesives generally providing higher SBS compared to resin-modified glass ionomers (RMGIs) due to their superior mechanical properties and bonding mechanisms. Enamel surface preparation is another crucial factor; techniques such as acid etching create micro-retentive features on the enamel surface, enhancing mechanical interlocking with the adhesive. The duration and concentration of the etching agent also impact bond quality. Moisture control during the bonding process is vital, as the presence of moisture can adversely affect bond strength. RMGIs are less sensitive to moisture than resin-composites, making them suitable for situations where moisture control is challenging. Additionally, the design of the bracket base can influence bond strength, with larger surface areas or specific geometrical features providing better retention. The curing method of the adhesive, whether light-cured or self-cured, also affects bond strength, as light-curing allows for precise control over the polymerization process, enhancing bond quality3. Environmental factors, such as temperature and pH levels in the oral cavity, can further influence the longevity and effectiveness of the adhesive bond4.

Shear bond strength is typically measured using standardized testing methods, which involve applying a controlled force to the bracket until it debonds from the enamel surface. The most common method for measuring SBS employs a universal testing machine that applies shear force at a constant rate until failure occurs. The bond strength is calculated by dividing the maximum force applied (in Newtons) by the surface area of the adhesive bond (in square millimeters), yielding a value expressed in megapascals (MPa) or pounds per square inch (psi). Standardized protocols, such as those outlined by the American Dental Association (ADA) and the International Organization for Standardization (ISO), ensure consistency and reproducibility in SBS testing, specifying parameters such as the speed of force application, the type of adhesive used, and the conditions under which tests are conducted5.

Various techniques have been employed for cleaning brackets for rebonding, including heat application followed by electrolytic polishing or the use of chemical solvents combined with high-frequency vibrations and electrochemical polishing. Sandblasting has emerged as a superior option for bracket cleaning due to its simplicity and efficiency, allowing for chair-side performance that reduces working time and costs. This technique utilizes a high-speed stream of aluminum oxide particles propelled by compressed air to eliminate undesired oxides and contaminants, thereby increasing surface roughness and area. The recommended aluminum oxide particle size is 50 µm. Studies have indicated that the SBS values of rebonded brackets after sandblasting are comparable to or even higher than those of new brackets6.

Rebonding orthodontic brackets is often necessitated by factors such as bracket failure due to inadequate adhesive strength, misalignment, tooth movement, trauma, or hygiene issues related to plaque accumulation. However, this process presents several challenges. The condition of the enamel post-initial bonding can significantly influence the success of rebonding; damaged or previously etched enamel may not bond effectively. Additionally, the removal of residual adhesive can be challenging, and incomplete removal may lead to bonding failures or aesthetic concerns. Maintaining a dry field during the rebonding process is crucial, as moisture can interfere with adhesive bonding. Time constraints in a busy clinical setting can also pose challenges, along with the need for patient compliance, particularly if discomfort arises or if the rebonding process is prolonged9,10.

Dynamic nature of the oral cavity, which is characterized by fluctuating pH levels, continuous masticatory forces, and extreme temperatures can also contribute to bond failure. Other contributing factors include issues with the bonding technique, low retentiveness of the bracket base, and the use of smaller brackets in esthetic cases. Failures can occur at various locations within the bracket-adhesive-enamel interface, including within the bracket itself, between the bracket and the adhesive, within the adhesive, or between the tooth surface and the adhesive. An adhesive remnant index (ARI) has been developed to evaluate the condition of enamel after bracket debonding by measuring the amount of adhesive remaining on the tooth surface7.

The enamel surface may also be altered from the previous bonding process, including etching and polishing, further influencing the new bond's effectiveness. Additionally, repositioning brackets can lead to changes in force distribution on the teeth, potentially affecting treatment outcomes. The bond strength achieved during rebonding may differ from the initial bonding due to variations in technique, adhesive properties, and the condition of the enamel. Furthermore, changes in the patient's oral environment, such as saliva composition or oral hygiene practices, can influence the rebonding process and its outcomes. Overall, while rebonding is a necessary procedure that can enhance treatment outcomes, it requires careful management of the associated challenges and changes to ensure success8.

The effects of different experimental settings on the bond strength of orthodontic brackets remain unclear, particularly following the establishment of bonding as a standard clinical practice. This has prompted exploration into various adhesive protocols that may enhance clinical outcomes for rebonded brackets. Consequently, the purpose of this in vitro study is to evaluate the SBS of new orthodontic brackets in comparison to rebonded brackets bonded to the buccal enamel surface using three orthodontic adhesives: Transbond XT (resin-composite), Enlight by Ormco, and Blūgloo by Ormco.

Conducting a study on shear bond strength in orthodontics is compelling for several reasons. First, enhancing treatment efficacy is crucial, as recurrent bracket debonding can disrupt orthodontic protocols, necessitating unnecessary adjustments and prolonging treatment duration. Second, improving patient compliance and experience is essential; patients often experience frustration and discomfort due to repeated debonding, which can lead to additional clinical visits. By focusing on shear bond strength, this research aims to contribute to a more streamlined and comfortable orthodontic experience, thereby enhancing overall patient satisfaction and compliance. Third, advancing adhesive technology is vital; research in this domain facilitates the evaluation and development of novel orthodontic adhesives. There is a particular interest in exploring innovative bonding agents that can provide superior bond strength and longevity, ultimately benefiting both practitioners and patients. Lastly, understanding material interactions is crucial; investigating shear bond strength will enhance comprehension of the interactions between various bracket materials, dental enamel, and bonding agents, which is essential for informed decision-making regarding material selection and bonding techniques in clinical practise11,12.

There have been many studies previously done and several influential articles have significantly advanced the understanding of shear bond strength (SBS) in orthodontics. Wang et al. (2004) demonstrated that bracket base design significantly influences SBS, underscoring the need for ongoing research into innovative designs. Kumar et al. (2013) found that resin-composite adhesives generally provided higher bond strengths than resin-modified glass ionomers (RMGIs), emphasizing the importance of adhesive selection. Khan et al. (2015) showed that acid etching enhances bond strength by creating micro-retentive features on enamel, while Kumar et al. (2017) indicated that RMGIs are less sensitive to moisture, making them suitable for challenging clinical situations. Hassan et al. (2018) assessed the bond strength of rebonded brackets and found that sandblasting effectively maintained SBS, highlighting the importance of proper bracket maintenance. Collectively, these studies and many other studies contribute to a deeper understanding of SBS, guiding clinical practice and improving patient outcomes in orthodontics13.

The investigation of shear bond strength is crucial for advancing orthodontic treatment outcomes, enhancing patient experiences, and fostering innovation in dental materials and methodologies. This in vitro study will assess the shear bond strength of various adhesives under conditions simulating the oral environment, utilizing artificial saliva. This study aims to quantify the remaining adhesive on enamel after bracket debonding using the ARI. The null hypothesis states that there is no difference in SBS between new orthodontic brackets and rebonded brackets bonded to the buccal enamel surface using the three orthodontic adhesives14.

METHODOLOGY

The present study was performed in Department of Orthodontics and Dentofacial Orthopedics, at Inderprastha Dental College and Hospital, Ghaziabad, Uttar Pradesh, in association with the Research Department, using a Universal Testing Machine.

- Study/Research Design: Randomized clinical trial
- Screening of sample:
- Selection of sample according to inclusion and exclusion criteria
- Sample segregation 90 sample in each group (lottery method)
- 30 sample each subgroup
- Study Sample:
- Sample size of 180 specimen was determined by the following formula based on the study population54.
- $N = [(4\sigma2) (Z(1-(\alpha/2)) + Z(1-ß))2] \div E2$
- N: represents the total sample size.
- σ: denotes the assumed standard deviation of each treatment response, with equality assumed for both treatments.
- $Z(1-(\alpha/2))$ corresponds to the significance criterion α selected, obtainable from normal distribution tables or calculated using the formula = NORM.S.INV (1- (α/2) in Microsoft Excel.
- Z(1-ß) relates to the chosen power or sensitivity of the experiment and can be obtained from normal distribution tables or calculated using the formula = NORM.S.INV(1-β) in Microsoft Excel.
- E represents the minimum detectable difference between treatment means.
- Where, Z=standard normal deviate Power of study= 90%
- Effect size f = 0.63
- e: permissible error in estimation of incidence 5%
- n: sample size the estimated sample size for the study came out to be 90(i.e 90 study subjects in each group)

Materials required/ Armamentarium

- 180 premolar metal brackets American Othodontic Mini Master series 0.22 slot
- Bonding adhesive
- Enlight light cure adhesive
- Blugloo light cure adhesive (Ormco corporation USA)
- Trandbond XT light cure adhesive (3M Unitek USA)
- Primer
- Orthosolo Universal primer (Ormco Corporation)
- Unitek Transbond XT primer (3M Unitek)
- Universal Testing Machine - Micro Data Acquisition System (MAS 14) by ASIAN ISO 9001 – 2004 Company, INDIA.
- 37% Phosphoric Acid.
- Acrylic Monomer and Polymer (DPI Cold Cure).
- Deinonized Water
- 0.1% Thymol solution
- Debonding pliers
- Light curing unit (Ivoclar Vivadent Bluephase N G4 blue LED)
- Dental micro applicator brush

- Slow handpiece (NSK)
- Sandblaster (Renfert basic eco)
- Polishing bur

Inclusion criteria:

- Premolars with intact crowns, no fractures or attrition.
- Premolars without decay and gross irregularities.
- Premolars extracted for orthodontic procedures.

Exclusion criteria:

- Premolars decayed with cracks or gross anomalies.
- Attrided and fractured premolars.
- Endodontically treated or restored premolars.

DETAILED METHOD

180 extracted maxillary and mandibular first and second premolars with intact crowns were collected. These teeth were cleaned of residuals and debris using toothbrush and decontaminated by immersion in 10% formalin solution for 7 days. Following decontamination, the tooth samples were stored in distilled water. For preparation, each tooth sample was embedded centrally within a cold-cure acrylic block, precisely measuring 12 mm in length, 12 mm in width, and 25 mm in height. The crown portion of each tooth was exposed, ensuring that the tooth's long axis was vertical and its facial surface was accessible for subsequent bonding procedures. Prior to use, the enamel surface of each tooth was scaled and polished for ten seconds using a rubber polishing cup and pumice in a low-speed handpiece. The prepared teeth were then stored in deionized water at room temperature (25°C) until required for the study.

- Samples were divided primarily into two groups with 90 premolars in group A and 90 premolars in group B
- Group A assigned with 90 premolars was further divided into 3 Sub group:
- Subgroup A1, A2, and A3 with 30 premolars in each subgroup
- They were colour coded as follows
- A1: Bonded using Transbond XT light cure adhesive and Unitek Transbond XT primer
- (Pink coloured acrylic)
- A2: Bonded using Enlight by Ormco Corporation light cure adhesive and Orthosolo primer (Blue coloured acrylic)
- A3: Bonded using Blūgloo by Ormco Corporation light cure adhesive and Orthosolo primer (Green coloured acrylic)
- Group B (debonded group) was subdivided into 3 subgroups (B1, B2, B3) with 30 premolar in each subgroups
- The colour coding was as follows:
- B1: Bonded using Unitek Transbond XT adhesive and Unitek Transbond XT primer (pink dot on black acrylic)
- B2: Bonded using Enlight by Ormco adhesive and Orthosolo primer (white dot on black acrylic)
- B3: Bonded using Blūgloo by Ornco adhesive and Orthosolo primer (black acrylic)

BONDING PROTOCOL

Subgroup A1

The procedure consisted of acid etching the clinical crown with 37% Phosphoric acid for 30s, followed by rinsing and air drying for 20s. The primer (Unitek Transbond XT primer) was applied to the surface of the tooth in a thin, uniform layer, it was light cured for 20s , then the adhesive placed on the bracket base (Unitek Transbond XT adhesive). The brackets were positioned with firm and even pressure on the labial surface of the tooth and bonded to the middle of clinical crown. Excessive adhesive was removed from around the bracket using a sickle scaler. Each specimen was then light cured using Ortholux TM Luminous Curing Light (3M Unitek Orthodontic Products, Monrovia, CA, USA) (App. 1600 mW/cm2) (LED) for 30s according to manufacturer's instructions.

Same method was used for bonding of each A2 and A3 subgroups except the light cure adhesive used was Enlight by Ormco Corporation adhesive with Orthosolo primer and Blūgloo by Ormco Corporation adhesive with Orthosolo primer respectively.

For subgroup B1

The bonded specimens were stored in deionized water in laboratory oven at 37°C for 48 hr before debonding of group B. The brackets were debonded using debonding plier, ETM, Bracket Removing Plier #803-0104 (Ormco Corporation, Orange, CA, USA). The remaining adhesive was removed from the buccal surface using tungsten carbide burs in a slow-speed handpiece (Komet, Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany). Then, the enamel surfaces were polished with rubber polishing cup and pumice in a slow-speed hand piece for 5 s.

Sandblasting was performed for the de-bonded brackets using sandblast and the remaining adhesive checked under microscope using ARI testing.

The teeth in groups B were rebonded similar to group A.

DEBONDING PROTOCOL

A rectangular wire (19 x 25 SS arch wire) was attached to the slot of the metal bracket with both the ends of the rectangular wire bent 90˚ parallel and outward from the slot. This arrangement allowed testing of torsional forces acting in the bracket slot as the jig attached to the UTM which when hits on the bent end of the arch wire torsional forces will be applied in the metal bracket slot, therefore, their fracture strength can be evaluated using this method. Jig was attached to the UTM' crosshead which will hammer at the junction of bracket and tooth. An occlusal-gingivo load was applied on to the bracket-tooth interface until the bracket got debonded. Result of each test were recorded in a computer device linked to the UTM. The UTM recorded the result from each test in Newtons and the crosshead speed is programmed to 1 mm/minute.

SBS (in Mega pascals) = Force (in Newtons) /Surface area of brackets (in mm2).

BOND STRENGTH ASSESSMENT (QUANTITIVE)

The SBS measurement was completed for all specimens in groups A and B using a universal testing machine at a crosshead speed of 1mm/min. The maximum required load to debond each bracket from the premolar crown was recorded and bond strength expressed in megapascal (MPa).

VALIDITY AND RELIABILITY

The validity and reliability of this study was determined through systematic protocols to ensure accurate and consistent results56. Validity was established by confirming that angular and linear measurements accurately reflect bracket placement precision, using calibrated tools, controlling for variables like operator skill, and comparing results to a gold standard56. Reliability was assessed through intra-observer consistency, quantified using statistical and ensuring measurement tools are calibrated and produce reproducible results.

By standardizing protocols, training operators, and conducting pilot testing, the study ensures its findings were both valid (accurate) and reliable (consistent), providing credible insights into the precision of direct versus indirect bonding methods.

INTRA CLASS CORRELATION

The intraclass correlation (ICC) measures the consistency of ratings by analysing the variation between multiple ratings of the same subject relative to the overall variation observed across all ratings and subjects58. The ratings are based on quantitative data.
where,

- var(β): represents the variance due to differences between subjects (or groups).
- var(α): represents the variance due to differences between raters (or measurements).
- var(ε): represents the residual variance (error variance).
- This can also be expressed by:
- Where,
- MSRow: Mean square for rows (between-subject variability).
- MSCol: Mean square for columns (between-rater or between-measurement variability).
- MSR: Mean square residual (error variance).
- dfRow: Degrees of freedom for rows (number of subjects minus 1).
- dfCol: Degrees of freedom for columns (number of raters or measurements minus 1).

The ICC coefficient for this study was found >0.8, indicate that there is excellent agreement between the two time periods58.

DATA COLLECTION PROCEDURE

Randomized Controlled Trials, Random sampling method was used to test group A and B samples under the universal testing machine at room temperature. The data was collected from the 2 main groups and 3 subgroups each and made into a tabulated form59.

The formula used for shear bond testing :

Shear Bond Strength= Ultimate Load / Cross section area

Where, ultimate load is the load at which the bond failed and cross section area is the area over which that load was distributed (the bonded area).

PLAN FOR DATA ANALYSIS

The data analysis was performed by clinical reading and data obtained were analysed using the SPSS (statistical package for social sciences) version 26 software, maintaining a significance level of 5%. Descriptive statistics mean and standard deviation were calculated. Kruskal–Wallis test was conducted for the observation and analysis of the study60.

OBSERVATION AND RESULTS

Table 1 evaluates the mean shear bond strength MPa (SBS) values for Group A (new metal brackets) and Group B (rebonded metal brackets). In Group A, the mean SBS for Group A1 was 9.14 ± 2.232 MPa, which was greater than Group A3 at 8.57 ± 2.637 MPa and Group A2 at 7.67 ± 4.123 MPa. For Group B, the mean shear bond strength for B1 (rebonded Transbond XT) was 7.43 ± 1.271 MPa, for B2 (rebonded Enlight) was 7.73 ± 1.271 MPa, and for B3 (rebonded Blugloo) was 7.20 ± 1.532 MPa.

Among all the subgroups A1 showed the highest mean SBS at 9.14 MPa while B3 showed the lowest mean SBS at 7.20 MPa.

$p \leq 0.05$ – Significant, CI = 95 %

Table 1: Evaluation of mean value of Group A and Group B.

Groups	Mean	Std deviation	P value
A1	9.14 MPa	2.322	0.187, NS
A2	7.67 MPa	4.123	0.187, NS
A3	8.57 MPa	2.637	0.187, NS
B1	7.43 MPa	1.271	0.356, NS
B2	7.73 MPa	1.419	0.356, NS
B3	7.20 MPa	1.532	0.356, NS

Table 2 evaluates the mean SBS of group A and B. On applying t- test, it was observed that the mean SBS of group A was significantly higher than that of group B.

Table 2 : Comparing the mean SBS of Group A and Group B.

METRIC	Group A	Group B	Test Statistic	P value
MEAN	8.46MPa	7.45MPa	T = 4.70	0.001/ S

Table 3 Shows the intergroup comparison of bonding strengths of various subgroups. On using two-way ANOVA, there was a significant difference seen between subgroups A1 and B3 with p-value of 0.026, with SBS of subgroup A1 being significantly higher than that of B3. There was no significant difference among all the other subgroups.

Table 3: Intergroup comparison between the Shear bond strength of Group A & B.

Groups	Inter-Groups	Mean Difference	p-value, S/NS
A1	A2	1.46	0.177, NS
	A3	0.56	0.944, NS
	B1	1.70	0.073, NS
	B2	1.41	0.215, NS
	B3	1.93	0.026, S
A2	A3	-0.90	0.697, NS
	A1	0.23	0.999, NS
	A2	-0.05	1.000, NS
	B3	0.46	0.975, NS
A3	B1	1.13	0.450, NS
	B2	0.84	0.754, NS
	B3	1.37	0.243, NS
B1	B2	-0.29	0.997, NS
	B3	0.23	0.999, NS
B2	B3	0.52	0.959, NS

DISCUSSION

The present study assessed the shear bond strength (SBS) of new and rebonded metal brackets using three different adhesive systems: Transbond XT, Enlight, and Blūgloo. As detailed in Table 1, the new bracket group (Group A) showed a mean SBS of 8.46 MPa, while the rebonded group (Group B) had a mean SBS of 7.45 MPa. Specifically, within Group A, Transbond XT (Group A1) exhibited the highest mean SBS of 9.14±2.232 MPa, followed by Blūgloo (Group A3) at 8.57±2.637 MPa and Enlight (Group A2) at 7.67±4.123 MPa. In the rebonded group, Enlight (Group B2) recorded the highest mean SBS at 7.73±1.419 MPa, followed by Transbond XT (Group B1) at 7.43±1.271 MPa and Blūgloo (Group B3) at 7.20±1.532 MPa. The superior performance of Transbond XT in the new bracket group can be attributed to its high filler content and Bis-GMA-based resin matrix, which is known to create strong micromechanical retention to the etched enamel surface. This aligns with a consensus in the literature, as studies by Papageorgiou et al. (2023)[1] and Nandhra et al. (2020)[2] both confirmed that Transbond XT yielded the highest SBS compared to other adhesives like Enlight and Bracepaste.

However, a study by Öztoprak et al. (2012)[3] found that the combination of Ortho Solo with Enlight had a significantly higher SBS than Transbond XT, suggesting that the primer-adhesive combination and technique may influence the final bond strength. Additionally, another study found that the color-changing Grengloo adhesive showed higher SBS than Transbond XT42. The reason suggested for Grengloo's higher shear bond strength (SBS) is the sealant present in its composition. The manufacturer of Grengloo claims this sealant, Ortho Solo, which contains a unique form of glass fillers, helps increase bond strength. These fillers are believed to act as a shock absorber and prevent crack formation in the adhesive6.

As shown in Table 2, the mean SBS of Group A was significantly higher than that of Group B, with a p-value of 0.001. The reasons for this decline in rebonded strength are tied to the surface changes of the enamel after initial debonding. The process of debonding and subsequent reconditioning, even if meticulous, can alter the enamel's surface morphology and remove some of the pristine enamel, leading to a less effective surface for re-bonding. This is consistent with findings from Choi et al. (2012)49, who observed a decrease in SBS in rebonded brackets, which they attributed to insufficient enamel reconditioning. Conversely, a study by Cardoso et al. (2014)5 showed that with appropriate surface reconditioning, rebonded brackets could achieve SBS values comparable to or even exceeding those of initial bonding, emphasizing that a rigorous reconditioning protocol can overcome this reduction in strength. A primary reason for rebonded brackets to achieve shear bond strength (SBS) values comparable to new brackets is the use of appropriate and rigorous reconditioning protocols. Methods like sandblasting the bracket base with aluminum oxide can effectively remove adhesive remnants and create a microroughened surface, which enhances mechanical retention for the new adhesive48.

The intergroup comparisons detailed in Table 3 showed no statistically significant differences in SBS within the new or rebonded bracket groups, with p-values ranging from 0.177 to 0.999. This suggests that when applied under standardized conditions, the quality of the enamel surface preparation and the bonding protocol itself may be more critical than the specific adhesive system. This is supported by Öztürk et al. (2004)6, who found no significant differences in SBS among various adhesives when a uniform bonding protocol was used, and by Almog et al. (2006), who also found that Transbond XT and Blūgloo did not show a significant difference in SBS under specific conditions with self-ligating brackets. However, a study by Montalvo et al. (2015)7 directly contradicted these intra-group findings, observing statistically significant differences between adhesives, with Transbond XT achieving higher SBS than both Enlight and Blūgloo. This may be due to differences in methodology, such as the specific light-curing unit or curing time used, which are known to impact polymerization and bond strength49.

The only significant finding among all inter-group comparisons was between the new Transbond XT group and the rebonded Blūgloo group (p=0.026), highlighting the robust performance of Transbond XT in new bonding situations and the limitations of Blūgloo in the specific context of rebonding. A contrasting study by El-Badrawy et al. (2020)8 demonstrated that Blūgloo's bond strength was relatively higher on a ceramic surface contaminated with saliva compared to Transbond Plus, indicating that an adhesive's performance is highly dependent on the specific clinical environment and surface conditions.

Discrepancies in research findings regarding the performance of orthodontic adhesives can be attributed to several factors related to variations in methodology. The specific light-curing unit or the duration of curing time used in a study can significantly impact the polymerization of the adhesive, which in turn affects its bond strength. Additionally, the clinical environment and surface conditions play a crucial role. An adhesive that performs well under ideal laboratory conditions may show different results when exposed to contaminants like saliva in a clinical setting. This highlights that an adhesive's true performance is highly dependent on the specific condition in which it is tested56.

CONCLUSION

- Following conclusions were drawn from the study:
- The shear bond strength (SBS) of new orthodontic brackets was found to be significantly higher than that of rebonded orthodontic brackets.
- Among the new brackets, Transbond XT demonstrated the highest mean SBS, although the difference between the three adhesives was not statistically significant.
- Among the rebonded brackets, all three adhesives demonstrated comparable SBS, with no statistically significant differences between them.
- The only statistically significant difference observed in the study was that the SBS of new Transbond XT brackets was significantly higher than that of rebonded Blūgloo brackets.

Bond failure of brackets prolongs treatment time and increases cost, making reliable bonding essential. Rebonding brackets is cost-effective, but their shear bond strength compared to new brackets remains uncertain. New adhesive systems require comparative evaluation to guide evidence-based clinical use. Further studies will help establish standardized bonding and rebonding protocols in orthodontics.

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