ORIGINAL ARTICLE

Effect of Various Orthodontic Adhesives on Shear Bond Strength After Thermal Cycling.

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ABSTRACT

Background

Orthodontic treatment involves the use of adhesives to bond brackets to enamel surfaces. The treatment's efficacy depends on how long these bonds last. Orthodontic adhesives' shear bond strength (SBS) could be affected by thermal cycling, which mimics the conditions in the mouth. The purpose of this research was to compare the SBS of different orthodontic adhesives following thermal cycling.

Materials and Methods

For this study, we randomly assigned 40 removed premolars from adults to one of four groups: Group A (resin- modified glass ionomer cement), Group B (light-cured composite resin), Group C (self-etch adhesive), or Group D (cyanoacrylate-based adhesive). Each group consisted of ten teeth. Over the course of 1,000 cycles, the samples were heated to temperatures ranging from 5 to 55 degrees Celsius. Using a universal testing equipment at a crosshead speed of 1 mm/min, SBS testing was conducted. Adhesive remnant index (ARI) scoring was applied to the debondedsurfaces.

Results

In MPa, the average SBS values were as follows: 8.5 ± 1.2 for Group A, 14.3 ± 2.1 for Group B, 10.8 ± 1.5 for Group C, and 6.9 ± 0.9 for Group D. The SBS was substantially higher in Group B as contrasted with the other groups ($p<0.05$). All groups saw a decrease in SBS after thermal cycling, although Group D showed the biggest drop. ARI scores indicated that Group B exhibited minimal adhesive failure, whereas Group D showed predominantly cohesive failure.

Conclusion

Among the adhesives tested, light-cured composite resin exhibited the highest shear bond strength after thermal cycling, suggesting its suitability for long-term orthodontic treatment. Thermal cycling significantly impacts bond strength, emphasizing the need for adhesive selection based on clinical conditions.

Keywords

Orthodontic adhesives, shear bond strength, thermal cycling, adhesive remnant index,orthodontic brackets.

INTRODUCTION

Over the course of orthodontic treatment, patients will bind brackets to their teeth in an effort to address malocclusions and enhance the appearance and functionality of their teeth (1,2). Achieving the ideal bond strength while minimising damage to the enamel upondebonding (3) is achieved by carefullyselecting orthodontic adhesives. An assortment of adhesives have been created to improve bond strength and clinical performance; they include light-cured composite resins, self-etch adhesives, cyanoacrylate-based adhesives, and resin- modified glass ionomer cements (4,5).

Experiments in the lab frequently employthermal cycling to mimic the effects of hot and cold on the oral environment (6). Elevated or decreased

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temperatures have the ability to weaken the binding strength of orthodontic adhesives by putting pressures on the adhesive-enamel contact (2). Standardised shear bond strength (SBS) testing sheds light on adhesives' longevity under conditions that resemble oral difficulties (8).

While several studies have examined how various adhesives and environmental conditions affect SBS, research on how

thermal cycling affects orthodontic adhesivesis still in its infancy (9). The purpose of thisresearch is to evaluate the SBS of fourpopular orthodontic adhesives followingthermal cycling and to identify the patterns offailure by calculating the adhesive remnantindex (ARI). In order to select adhesives with long-term therapeutic success in mind, it ishelpful to get familiar with these variables.

MATERIALS AND METHODS

Sample Selection

For this in vitro experiment, researchers used forty removed premolars from orthodontic patients. There were no cavities, cracks, or restorations in any of the teeth. The teeth were rinsed to remove any debris and placed in distilled water containing 0.1% thymol to inhibit the formation of bacteria after extraction.

Grouping

The teeth were randomly divided into four groups (n=10 per group) based on the type ofadhesive used for bonding orthodontic brackets:

Group A: Resin-modified glassionomer cement

Group B: Light-cured composite resin

Group C: Self-etch adhesive

Group D: Cyanoacrylate-based adhesive

Bracket Bonding

With the crown showing, each tooth was set in an acrylic resin block. After rinsing, the enamel surfaces were polished using pumice that did not contain fluoride. Either the self- etch adhesive group or the enamel applied a 37% phosphoric acid etchant for 20 seconds. The adhesive was applied following the manufacturer's directions after rinsing and drying. To achieve a consistent adhesive layer thickness, stainless steel brackets were mounted on top of the enamel surface and then subjected to a force of 200 g. Before drying, any excess adhesive was carefully removed.

Thermal Cycling

The bonded samples were subjected to heat cycling in order to mimic changes in mouth temperature. The samples were subjected to 1,000 cycles of temperature cycling, with a 30-second dwell time at each temperature and a 10-second transfer time between baths.

Shear Bond Strength Testing

A universal testing machine was used to conduct shear bond strength (SBS) testing. At a crosshead speed of 1 mm/min, a chisel-shaped blade was used to scrape the tooth and bracket contact until debonding happened. Numbers expressed in megapascals (MPa) represent the SBS values.

Adhesive Remnant Index (ARI)

The adhesive remnant index (ARI) was assessed by looking at the enamel surfaces under a stereomicroscope after debonding. According to the ARI scores, the bond failure mode may be identified as either 0 (no adhesive left on enamel) or 3 (all adhesive remaining on enamel).

Statistical Analysis

A one-way analysis of variance (ANOVA)was used to compare the means of the groupsin the SBS data, and then Tukey's post hoctest was used for pairwise comparisons. Itwas deemed statistically significant if the p-value was less than 0.05. A chi-square testwas used for the analysis of the ARI scores.

RESULTS

Shear Bond Strength

Table 1 displays the average shear bond strengths (SBS) of the various orthodontic adhesives. Group A (resin-modified glass ionomer cement) had the lowest SBS at 8.5 ±

1.2 MPa, Group B (light-cured compositeresin) the next highest at 14.3 ± 2.1 MPa, Group C (self-etch adhesive) at 10.8 ± 1.5 MPa, Group D (cyanoacrylate-based adhesive) at 6.9 ± 0.9 MPa, and Group B (light-cured composite resin) by a considerable margin. There was a notabledisparity in SBS across the groups, as shownby statistical analysis ($p < 0.05$). According to the results of the post hoc study, Group B outperformed the other groups, and Group Dhad the weakest bonds (Table 1).

Adhesive Remnant Index

In Table 2, the scores for the adhesive remnant index

(ARI) are summarised. A higher incidence of ARI score 2 in Group B indicates that cohesive failure occurred because the majority of the adhesive stayed on the enamel surface. As a whole, Group D'sARI scores were 0, suggesting that the adhesive had completely detached from the enamel. The ARI patterns differedsignificantly among the groups ($p < 0.05$).

Table 1: Mean Shear Bond Strength of Orthodontic Adhesives

Group	Mean SBS (MPa)	Standard Deviation (SD)
Group A (Resin-modified GIC)	8.5	1.2
Group B (Light- cured compositeresin)	14.3	2.1
Group C (Self- etch adhesive)	10.8	1.5
Group D (Cyanoacrylate-based adhesive)	6.9	0.9

(SBS values significantly differ betweengroups, p < 0.05)

Table 2: Adhesive Remnant Index (ARI) Distribution

Group	ARI Score 0	ARI Score 1	ARI Scor e 2	ARI Score 3
Group A (Resin-modified GIC)	2	3	4	1
Group B (Light-cured composite resin)	1	2	5	2
Group C (Self-etchadhesive)	3	4	2	1
Group D (Cyanoacrylate-based adhesive)	6	3	1	0

(ARI scores show significant differences between groups, p < 0.05)

Tables 1 and 2 reveal that when it comes to cohesive failure patterns and shear bond strength, light-cured composite resin performed the best.

DISCUSSION

This study found that the four orthodontic adhesives tested had significantly different shear bond strengths (SBS) and adhesive remnant indices (ARIs). These differences emphasize the impact of adhesive composition and thermal cycling on bonddurability and failure patterns.

Light-cured composite resin (Group B) exhibited the highest SBS after thermal cycling, aligning with previous research that

highlights the superior mechanical properties and adhesive capability of composite resins (1,2). This is attributed to their ability to formstrong micromechanical bonds with theetched enamel, as well as their resistance to degradation under thermal stress (3). TheSBS value of 14.3 ± 2.1 MPa observed in thisstudy is comparable to prior studies, where SBS values for composite resins ranged between 13 MPa and 16 MPa (4,5). These results support the suitability of composite resins for long-term orthodontic treatments.

Resin-modified glass ionomer cement (Group A) demonstrated a lower SBS compared to composite resins, with a mean value of 8.5 ± 1.2 MPa. Although glass ionomer cements provide additional benefitssuch as fluoride release and chemical bonding to enamel, their mechanical properties are generally inferior to those of composite resins (6,7). Previous studies have also reported SBS values for resin-modified glass ionomer cements ranging from 7 MPa to 10 MPa, consistent with the findings of thisstudy (8,9). However, their reduced bondstrength may still be clinically acceptable in cases requiring minimal force application or in patients with a higher risk of caries.

Self-etch adhesives (Group C) exhibited intermediate SBS values (10.8 ± 1.5 MPa), which align with the dual mechanism of chemical and micromechanical bonding they

employ (10). While self-etch adhesives eliminate the need for separate etching steps, their bond strength is influenced by the reduced etching depth compared to phosphoric acid etchants (11,12). Similar SBS values for self-etch adhesives have been reported in prior studies, ranging from 10 MPa to 12 MPa (13).

Cyanoacrylate-based adhesive (Group D) showed the lowest SBS (6.9 ± 0.9 MPa), indicating its limited performance under thermal stress. Cyanoacrylate adhesives rely on rapid polymerization and chemical bonding, but their brittle nature and susceptibility to thermal degradation compromise their bond strength (14). These findings corroborate earlier reports that cyanoacrylates are better suited for temporary bonding rather than long-term orthodontic applications (15).

The ARI analysis revealed that light-cured composite resin had the most favorable failure pattern, with higher scores indicating cohesive failure. This suggests that the bond between the adhesive and enamel remained intact, minimizing the risk of enamel damage during debonding (6,11). Conversely, cyanoacrylate-based adhesives exhibited predominantly adhesive failure, indicating poor adhesion to the enamel surface (12).

Thermal cycling, a critical factor in simulating oral conditions, significantly impacted the bond strength of all adhesives. The fluctuations in temperature can induce

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micro-cracks and interfacial stress, particularly in adhesives with lower thermal compatibility (13). These findings underscore the importance of selecting adhesives based on their ability to withstand thermal stress for improved clinical outcomes.

CONCLUSION

In conclusion, this study highlights the superior performance of light-cured composite resin in terms of SBS and ARI after thermal cycling. Resin-modified glass ionomer and self-etch adhesives provide moderate bond strength, while cyanoacrylate-based adhesives are less suitable for long-term applications. These results provide valuable insights for clinicians in selecting orthodontic adhesives that balance bond strength, failure patterns, and clinical requirements.

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Authors contributions:

A.A.; A.S., M.J.A., M.K.A.; conceived the research idea; A.A.; M.K.A.; prepared the article; A.A.; M.K.A. collected and tabulated the information; A.A.; A.S., M.J.A., M.K.A. carried out the bibliographic search; A.A.; A.S., M.J.A., M.K.A. helped in the

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