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Renewing Orthodontic Bonds: Comparison of Shear Bond Strength of Metallic Orthodontic Brackets after Recycling the Brackets and Enamel Clean-Up Using Different Methods

Zahid Sana[1], Shantanu Sharma[2], Anamika jakhar[3], Nidhi [4], Mufti Sheheer[5], Umang Malviya[6]

[1,5]Third year Post Graduate Resident, Department of Orthodontics and Dentofacial Orthopaedics, Nims University Rajasthan, Jaipur, India

[2]Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Nims University Rajasthan, Jaipur, India

[3,4]Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Nims University Rajasthan, Jaipur, India

[6] Second year Post Graduate Resident, Department of Orthodontics and Dentofacial Orthopaedics, Nims University Rajasthan, Jaipur, India

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KEYWORDS

Shear bond strength, Adhesive remnant index, Bracket Recycling, Bracket base, enamel clean-up

ABSTRACT

Aim: To evaluate and compare the shear bond strength of metallic orthodontic brackets after recycling of the brackets and cleaning the post de-bonded enamel surface, using different methods.

Materials and methods: In this research 54 non-carious premolar teeth were selected and divided into two groups, A and B (27 each). All the teeth were bonded with metallic brackets. Shear bond strength of these teeth was measured by Universal Testing Machine. Debonded teeth in group A were cleaned with Carbide bur and Soflex polishing discs while teeth in group B were cleaned with Ultrasonic scaling and Sandblasting. Bracket bases in both the groups were recycled with Buchman method. The recycled brackets were rebonded to the teeth and Shear bond strength was measured again with Universal Testing Machine.

Results: Following recycling, there was a discernible drop in shear bond strength (SBS) for both Group A and Group B. Teeth cleaned with carbide bur and soflex polishing discs showed better results.

Conclusion: Recycling the tooth surface using a carbide bur and soflex polishing disc led to significant increase in shear bond strength (SBS) compared to cleaning the surface with ultrasonic scaling and sandblasting.

Introduction

Fixed orthodontic treatment relies on strong bonding between brackets and enamel, crucial for enduring attachment throughout treatment, resisting shear forces and tension. [1]

Direct bracket bonding to tooth surface became possible with the advent of acid etching which revolutionized the orthodontic practice. [2] The failure of a bonded orthodontic bracket during the course of therapy is not an uncommon occurrence. [3] Orthodontic brackets can be accidentally dislodged due to trauma or for repositioning. Orthodontists must decide what to do with used brackets, proposing eco-friendly alternatives to disposable practices, saving costs for both providers and patients. [4]

Orthodontic bracket recycling aims to cleanly remove adhesive from the base without harm, ensuring purity for strong rebonding to enamel. [5] Various chairside

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methods exist for recycling orthodontic brackets, including mechanical (e.g., air rotor handpiece, ultrasonic scaling, sandblasting), thermal (e.g., direct flaming, furnace heating), and combined approaches (e.g., Buchman method - flaming, sandblasting, electropolishing). [6]

Advancements in bonding technology made direct bracket bonding safe and effective, but bracket removal and enamel polishing post-debonding remain challenging, leading to research on safe and efficient chairside methods and tools. [7]

Orthodontic biomaterials ideally balance adhesion to withstand chewing forces (5–10 MPa) without excessive strength to prevent enamel damage post-debonding (40–50 MPa), aiming for a bonding force range of 5–50 MPa, though these limits are largely theoretical. [8]

Heat plays a crucial role in bracket recycling, affecting the microstructure of austenitic stainless-steel brackets. Heating between 400°C and 900°C forms chromium carbide precipitates, weakening the alloy and reducing corrosion resistance. Temperatures above 650°C soften the metal irreversibly, affecting hardness and tensile strength. [9]

Electropolishing recycled brackets is vital to smooth surfaces, enhancing patient comfort and minimizing tarnish or corrosion risks. [9] Sandblasting of unbonded metal brackets produces satisfactory bond strength. [10] The primary orthodontic goal lies in returning the enamel surface to its original state after removal of orthodontic attachments. [11]

This study aims to assess and compare the shear bond strength of metal orthodontic brackets following bracket recycling and post-debonded enamel surface clean-up, employing various methods.

Method

Before the start of this in-vitro study, approval was obtained from the Institutional Ethics Committee**,** with ethical reference no. IEC/P-11/2022.

Study included extracted human premolar teeth that were non-carious and demineralization-free. The teeth also were free of any indications of fluorosis and show no evidence of wear or abrasion.

Study excluded the teeth that were carious, severely worn due to attrition or abrasion, those with areas of demineralization, and teeth exhibiting signs of fluorosis. The SBS of metallic brackets for orthodontic treatment was compared in an experimental investigation employing various techniques for enamel cleansing and bracket recycling. The fifty-four non-carious premolar teeth that were removed and cemented with metallic brackets as part of a regular orthodontic treatment plan were the subjects of the study. The SBS of teeth was established using the INSTRON Universal Testing Machine

Teeth had been preserved in solution of saline post extraction. Following brushing and pumice powder cleaning, two equal groupings of teeth were created, Groups A and B, each with twenty-seven teeth. Group A's teeth had been embedded in orthocal, (Fig.1A) while Group B's teeth were set in green stone (Fig.2A).

All fifty-four teeth were bonded with Victory series 3M™ MBT metallic brackets. In line with the advice provided by the manufacturer, 37% phosphoric acid, light cure primer and adhesive (3M Unitek) were used to bond brackets. The same specialist bonded each bracket, placing them in the exact center of the prepared tooth surfaces that had been prepared. They were securely pushed, area surrounding the bracket base was cleaned of extra adhesive by means of a probe. (Figs. 1B and 2B). Using a curing light (LED; woodpecker I LED), the composite underwent light curing for ten seconds.

As the control group, fifty-four bonded premolars were employed, and they underwent SBS testing using an INSTRON UTM. Using a rod at a steady pace of 0.5 millimeters per minute until failure was noticed, an applied force was in line with the buccal surface of the tooth and directed gingivo-occlusally. The force required for bracket debonding, the SBS values were calculated in megapascals (MPa) quantified in Newtons (N).

Group A (27 Teeth):

After deboning the brackets, the tooth surface was cleaned with Carbide bur and Sof-Lex polishing discs (Fig.1C).

Debonded metal bracket bases were recycled using the Buchman method i.e., The brackets were heated for five to ten seconds, or until the adhesive began to burn,

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using a flame from a Bunsen burner. Following that, they were submerged in water at ambient temperature and rapidly chilled. After that, each bracket was subjected to a 5-second sandblasting process using 50 µm alumina particles at a distance of ten mm and nine bars of pressure. This was done using Microetcher IIA equipment. This was followed by an electropolishing step to complete the surface treatment process.

All twenty-seven teeth were rebonded utilizing recycled metallic brackets after recycling. UTM was used to measure the SBS by placing a load in a gingivo-occlusal orientation parallel to buccal surface of the tooth. This was accomplished by using a rod that advanced until the point of failure was reached at a steady pace of 0.5 millimeters per minute (Fig.1D). The SBS values were computed by precisely measuring the force needed to debond the brackets.

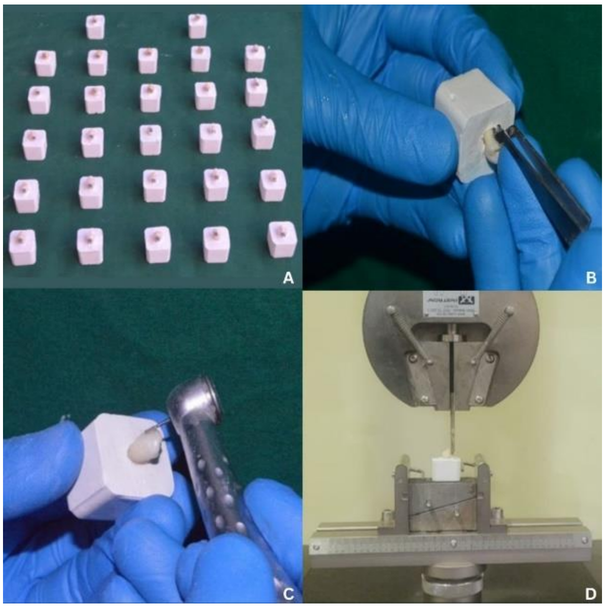

Fig. 1: (A) Teeth in group A mounted in orthocal, (B) Bonding of bracket on tooth in group A, (C) Tooth surface cleaning with Carbide bur, (D) Universal Testing Machine - INSTRON 5900 S, Shear bond strength measurement in group A.

Group B (27 Teeth):

After deboning the brackets, the tooth surface was cleaned with Sandblasting and Ultrasonic scaling (Fig.2C). Debonded metal bracket bases will be recycled using the Buchman method.

All of the teeth in group B were rebonded using metallic brackets after recycling, and UTM was used to measure the SBS (Fig.2D). A bracket's debonding force was measured, and the resulting value was computed to estimate the SBS.

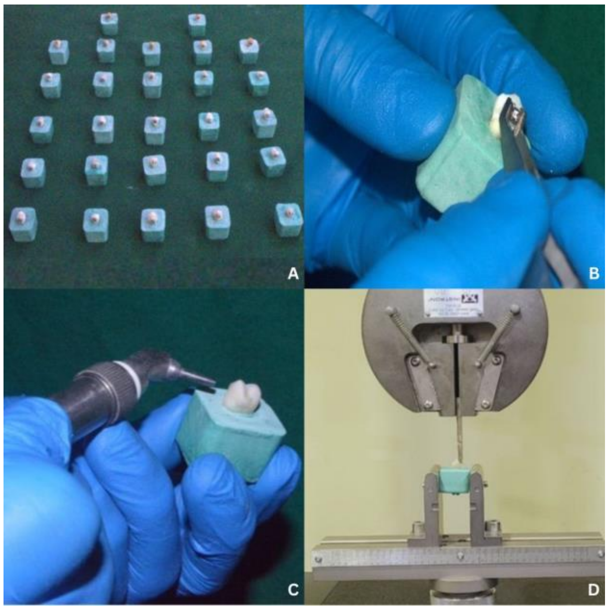

Fig. 2: (A) Teeth in group B mounted in greenstone, (B) Bonding of bracket on tooth in group B, (C) Tooth surface cleaning with Sandblasting, (D) Universal Testing Machine - INSTRON 5900 S, Shear bond strength measurement in group B.

Statistical Analysis

Data were coded in Excel and analysed with SPSS v29.0.2.0. Normality, confirmed by Kolmogorov-Smirnov test ($p = 0.008$), allowed parametric tests. Descriptive stats were computed. Mean Shear Bond Strength (MPa) values were graphed. Intragroup comparisons used paired t-tests ($p < 0.001$), while intergroup comparisons used unpaired t-tests ($p < 0.001$), all at a 5% significance level.

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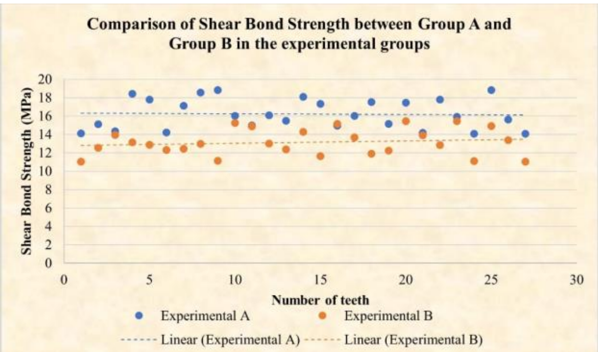
Results

The control subgroup has stable SBS across different teeth counts, while the Experimental subgroup has lower but consistent SBS values. Both show a positive association with tooth count and linear trend lines, with the Experimental subgroup consistently below the Control subgroup.

Group B's SBS in control and experimental subgroups. SBS is consistent across teeth counts, with Control subgroup showing higher SBS values. The Experimental subgroup has lower but consistent SBS, with some variability. A moderate correlation is observed, with data points dispersed around linear trend lines.



Graph 1: Shear Bond Strengths of Group A and Group B in experimental subgroups

Both A and B groups have most data points clustered at lower SBS values. Group A generally has higher SBS than Group B, with a positive correlation between SBS and tooth count observed in Group A. The trend lines fit the data well for both groups, with Group B showing less variability in SBS compared to Group A (Graph 1)

Group A's SBS mean and standard deviation are 18.55 ± 1.235 for control and 16.22 ± 1.635 for experimental. Group B's SBS mean and standard deviation are 18.77 ± 1.205 for control and 13.14 ± 1.416 for experimental. Group B shows a larger SBS reduction, highlighting the need to assess recycling's impact on dental material properties across different treatments (Table 1).

Table 1: Mean Shear Bond Strength (MPa) of control and experimental group

	GROUP A (n=27) (Buchman + Carbide Bur & Soflex Disc)		GROUP B (n=27) (Buchman + Scaling and Sandblasting)	
	Control	Experimental	Control	Experimental
Mean	18.55	16.22	18.77	13.14
Standard Deviation	1.235	1.635	1.205	1.416
Range	17.03 - 21.04	14.07-18.83	17.17 - 21.16	11.04-15.45

In Group A, the experimental treatment (Buchman + carbide bur & soflex disc) resulted in a range of 14.07-18.83 compared to the control's 17.03-21.04. In Group B, the experimental treatment (Buchman + scaling and sandblasting) showed a more significant reduction, with a range of 11.04-15.45 compared to the control's 17.17-21.16, indicating greater effectiveness.

Paired t-tests within both groups A and B were significant ($p < 0.0001$), rejecting the null hypothesis and confirming a statistical difference between Control and Experimental measurements in both groups (Table 2).

Intergroup comparison between group A and group B was highly significant ($p < 0.0001$), showing substantial differences in bond strengths for the experimental (recycled) groups.

Discussion

The study compares SBS of recycled orthodontic brackets using different methods: Group A with carbide burs and Sof-Lex discs, and Group B with scaling and sandblasting, followed by Buchman procedure Buchman DJ. (1980).[12] Findings are crucial for understanding how recycling impacts bond strength.

The findings indicate that after recycling, SBS significantly decreased in both Group A and B. However, group B, which underwent scaling and sandblasting, saw a more significant drop in SBS than Group A. This shows that the manner of enamel clean-up after debonding has a substantial effect on the potency of the bond in recycled brackets. Mean SBS values for both groups prior to recycling were comparable, demonstrating the effectiveness of the Buchman technique in retaining original bond strength.

Table 2 Statistical comparison of both groups with paired t-test and student t-test

	GROUP A (N=27) (Buchman + Carbide Bur & Soflex Disc) (Paired T-Test)	GROUP B (N=27) (Buchman + Scaling and Sandblasting) (Paired T-Test)	Intergroup Comparison (Student T-Test)
Mean difference	2.33	5.63	3.08
Standard Error Mean	0.42	0.36	-
Mean of differences	-1.29	-6.498	-
Standard Deviation of differences	2.17	1.85	-
t statistic	5.569	15.785	7.397
Degree of freedom (*df*)	26	26	50.958
p-value	<0.001*	<0.001*	<0.001*

The mean SBS, determined using the Buchman method, varied across different studies: 11.23±1.02 MPa, [5] 21.73±4.01 MPa, [4] and 19.7±3.4 MPa [6] in ceramic [5] and stainless-steel brackets. [4,6]

Furthermore, a detectable positive link exists between the number of teeth and SBS in both groups, albeit with some variation. The data show that the recycling process has a substantial impact on SBS, as seen by the larger reduction observed in Group B compared to Group A, highlighting the need of assessing the mechanical properties of dental materials after recycling.

In order to ascertain the impact of altering the testing machine's crosshead speed on the shear bond strength of orthodontic brackets, Bishara et al. (2005) conducted research. [13] The study found that reducing the crosshead speed from 5.0 to 0.5 mm/min during shear bond testing resulted in a roughly 57% improvement in shear bond strength and a halving of the standard deviation to mean value ratio, from 66% to 33%. Therefore, it would be more beneficial to identify the different parameters involved in shear bond testing so that the results may be used for comparison. In order to prevent bias, the cross-head speed was likewise standardized at 1 mm/min.

Al-Hity et al. (2012) report that the bond strength of ceramic brackets is higher than that of metallic brackets because of a higher degree of polymerization and stress reduction on the adhesive-bracket joint caused by a stronger adhesion to ceramics and light transmission. [14] The results of this study partially align with those of the previously stated investigations. The SBS of the metallic brackets is lower than the bond strength of the polycrystalline ceramic brackets partially bonded to lithium disilicate ceramic crowns and feldspar. Because the ceramic brackets used in orthodontic therapy look nicer, this is encouraging for adult orthodontics.

The adhesive remnants of the debonded brackets are observed using a basic microscope at a magnification of 15×, and they are scored using a modified ARI. At first, Årtun J, Bergland S (1984) provided ARI.[15] Modified ARI was then employed by Bishara SE and Trulove TS (1990).[16] Since the adhesive-enamel interface is where the bond breakdown happens, it is simpler for clinicians to remove adhesive residue from the tooth surface after bonding because doing so runs the risk of damaging the enamel and lengthening chairside visits.

This ground-breaking study explores the relationship between SBS using various enamel clean-up techniques, marking a novel endeavor in orthodontic research.

Overall, the study emphasizes the need of carefully selecting enamel clean-up approaches in orthodontic bracket recycling processes. While the Buchman approach appears to be effective at maintaining bond strength, the choice of enamel clean-up procedure has a considerable impact on bond integrity. To maximize orthodontic bracket recycling processes, more research might look into additional aspects influencing adhesive residual and bond strength distribution, such as different adhesive kinds and bracket materials. Furthermore, the clinical consequences of the identified variances should be investigated in order to make successful orthodontic treatment recommendations.

Conclusion

- Shear bond strength of newly bonded brackets was significantly higher than that of recycled brackets.
- Tooth surface recycled with carbide bur and soflex polishing disc (group A) showed significant increase in Shear bond strength compared to tooth surface cleaned with ultrasonic scaling and sandblasting (group B).
- Buchman method is effective but time-consuming approach for bracket recycling.

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