

Comparison of Shear Bond Strengths of Recycled Brackets Using Various Methodologies – An in Vitro Study

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Abstract

Introduction: Recycling of debonded orthodontic brackets is often required in clinical practice, but the method used may influence bond strength. This study aimed to compare the shear bond strength of brackets recycled using different techniques. Materials and **Methods:** One hundred extracted premolars and 100 metal brackets (0.022” × 0.028”) were divided into five groups (n=20). Group 1 served as control for primary bond strength. Brackets in groups 2–5 were debonded, stored in artificial saliva for 24 hours, recycled using direct flaming, ultrasonic cleaning, slow-speed carbide bur, or sandblasting, and then rebonded. Shear bond strength was measured using a Universal Testing

Machine, and values were recorded in megapascals (MPa).

Results: The control group demonstrated the highest bond strength. Among recycled brackets, sandblasting showed the highest shear bond strength, followed by slow-speed carbide bur, direct flaming, and ultrasonic cleaning.

Conclusion: Sandblasting proved to be the most efficient and satisfactory method for recycling orthodontic brackets, providing higher bond strength compared with other methods

Keywords: Trans bond XT; Metal brackets; Shear bond strength.

Introduction

Orthodontics continually seeks to streamline clinical procedures to save time and reduce costs. One persistent issue in orthodontic practice is the accidental or intentional dislodgement of brackets, often resulting from occlusal trauma or repositioning to achieve better alignment. In such instances, clinicians must decide whether to discard or recycle the brackets. Recycling emerges as an economical and environmentally responsible option that involves removing the residual bonding agent from the bracket base to facilitate reuse.¹ This approach not only cuts down on treatment expenses but also supports sustainable clinical practices.

Bracket bond failures are common and can be attributed to multiple factors such as occlusal stress during mastication, compromised enamel preparation—particularly in posterior teeth—and contamination by moisture during bonding. Specific challenges are observed in patients with deep bites, where mandibular anterior brackets face excessive occlusal forces, and during canine retraction, which can cause tripping forces on mandibular brackets.² To address these challenges, several recycling methods have been introduced. These include thermal techniques, where brackets are heated to 427–454°C to burn off resin followed by electropolishing to restore surface smoothness and remove oxide buildup, and chemical techniques involving acid-based resin removal solutions.^{3,4} In some cases, brackets are also placed in a bicarbonate bath post-electropolishing to neutralize residual electrolytes and enhance corrosion resistance.⁵

However, despite the procedural advantages, recycling may compromise bracket quality, leading to issues such as diminished identification markings, potential lack of sterility, and increased risk of cross-infection.⁶ The

clinical performance of recycled brackets is largely measured by their shear bond strength (SBS), defined as the force needed to fracture the bond interface under shear forces. Studies have shown that recycled brackets, especially after one cycle, can retain bond strengths comparable to new brackets. Regan et al and Egan et al. found that bond strength decreased significantly only after multiple recycling cycles.^{7,8}

Clinically acceptable SBS values are between 6–8 MPa, ensuring sufficient bracket retention without causing enamel damage. Exceeding 13–14 MPa may risk enamel fracture, while lower values could lead to frequent debonding.⁹ Studies have reported debonding rates of 4.7% for light-cured adhesives and 6% for self-curing adhesives over six months of treatment, indicating the practical relevance of ensuring optimal bonding.^{10,11} Thermocycling is frequently employed in in-vitro studies to simulate the oral environment and assess the long-term durability of bonding agents under temperature variations and moisture exposure.¹²

Recent work by Ibarra N, Sáez M et al. (2023) found that enamel reconditioning and bracket recycling did not significantly affect SBS. However, adhesive failure predominantly occurred at the cement-enamel interface, with over 50% of the adhesive remaining on the bracket surface when using light-cured composites (LCC) and resin-modified glass ionomers (RMGI).¹³ Although various bracket recycling techniques exist, their impact on SBS remains inconsistent across studies. Some methods yield results comparable to new brackets, while others show diminished bond strength.¹⁴

This research is thus designed to evaluate and compare the shear bond strength of recycled orthodontic brackets using different recycling methodologies. By analyzing their effectiveness, the study aims to develop

standardized, clinically viable recycling protocols that preserve bracket integrity, maintain reliable bond strength, and reduce both costs and environmental burden.

Material & Method

This in-vitro experimental study was conducted to evaluate and compare the shear bond strength (SBS) of orthodontic brackets recycled using different techniques with that of new, unused brackets. A total of 100 extracted human maxillary first premolar teeth, indicated for orthodontic extraction and free from caries, cracks, or structural defects, were selected for the study. The teeth were stored in 0.1% thymol solution to preserve their integrity until the commencement of the experiment. The sample size was calculated based on a power analysis using data from a previous study by Rajeshwar Singh et al. With a Type I error (α) of 5% and Type II error (β) of 10% (power of 90%), and assuming a standard deviation of 2.06 and a mean difference of 1.85 between groups, the minimum required sample size per group was determined to be 17. To account for a 10% expected sample loss, the sample size per group was rounded up to 20, resulting in a total of 100 samples divided equally into five groups.



Figure 1: Bonding Armamentarium

The specimens were randomly allocated into five groups. Group 1 served as the control, with new brackets bonded directly to the enamel. Groups 2 to 5 involved brackets that were initially bonded, then debonded, and subsequently recycled using different techniques before

rebonding. Specifically, Group 2 brackets were recycled using flaming with a micro torch followed by electro polishing; Group 3 used ultrasonic cleaning; Group 4 utilized mechanical removal of adhesive with a slow-speed round carbide bur; and Group 5 employed sandblasting with 110 μ m aluminium oxide particles. Each group consisted of 20 samples, and a color-coding system was used to identify groups during the experiment.

Before bonding, all teeth underwent prophylaxis using pumice and a rubber cup for 10 seconds. The buccal enamel surfaces were then etched with 37% phosphoric acid (Scotchbond – 3M ESPE) for 15 seconds, rinsed for 20 seconds, and dried with oil-free compressed air for 30 seconds. A thin, uniform layer of Transbond™ XT primer (3M Unitek) was applied to the etched surfaces. Metallic brackets were bonded using Transbond™ XT adhesive, positioned on the tooth, and excess adhesive was removed. Light curing was performed for 10 seconds on both occlusal and gingival surfaces (total 20 seconds) using the Blue phase N LED light-curing unit.



Figure 2: Bonded Samples

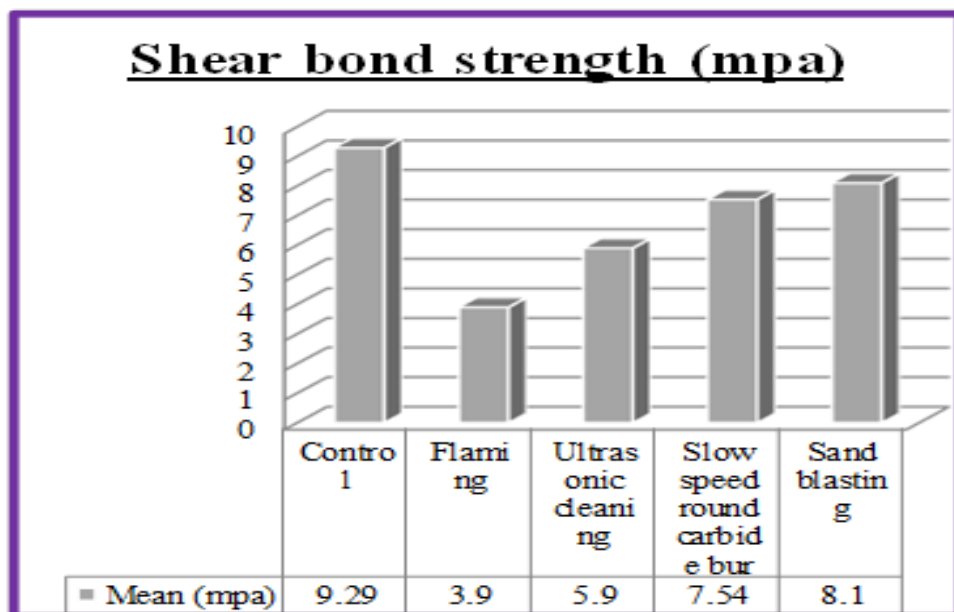
After initial bonding, brackets in Groups 2 to 5 were manually debonded using a direct bond bracket remover (SKODI, 001-346E). These brackets were immersed in artificial saliva for 24 hours to simulate intraoral conditions prior to recycling. The recycling procedures varied among the groups. Group 2 brackets were exposed to a gas microtorch (RS Pro MT 790) at 800–850°F for 5 seconds to burn off residual adhesive, followed by electropolishing to restore surface smoothness and remove oxide layers. In Group 3, ultrasonic cleaning was performed using an ultrasonic cleaner (Confident Dental Equipment Ltd, India). Group 4 brackets were cleaned using a 12-fluted round carbide bur in a slow-speed handpiece to mechanically remove adhesive remnants. In Group 5, brackets were sandblasted using an air abrasion technique with 110 µm aluminium oxide particles to eliminate residual bonding material.

Following recycling, brackets in Groups 2 to 5 were rebonded to the same tooth using Transbond™ XT

adhesive and primer. A high-intensity LED curing unit was used to cure the adhesive for 3 seconds, ensuring consistency in bonding conditions. The shear bond strength of all samples was tested using a Universal Testing Machine (Tinius Olsen) at the Department of Polymer Science, Cochin University of Science and Technology (CUSAT). Each tooth was mounted in an acrylic block and fixed on a universal joint to maintain parallel force application during testing. A beveled, flattened steel rod applied force at the bracket-tooth interface in an occlusogingival direction at a crosshead speed of 0.5 mm/min. The force required to cause bond failure was recorded in Newtons and subsequently converted into shear bond strength values (in MPa) by dividing the force by the bracket base area in mm².

The resulting data were statistically analyzed to determine differences in bond strength between groups and to identify which recycling method provided clinically acceptable and optimal shear bond strength values.

Result



Graph 1: Evaluation of the shear bond strength of recycled orthodontic brackets among the different methods

Table 1: Descriptive evaluation of the shear bond strength of recycled orthodontic brackets among the different methods

Evaluation of the shear bond strength of recycled orthodontic brackets among the different methods								
Variables	N	Mean (mpa)	Std. Deviation	Std. Error of Mean	Median	Minimum	Maximum	Range
Control	20	9.2900	.23598	.05277	9.3000	8.80	9.60	.80
Flaming	20	3.9000	.11239	.02513	3.9000	3.70	4.10	.40
Ultrasonic cleaning	20	5.9000	.11239	.02513	5.9000	5.70	6.10	.40
Slow speed round carbide bur	20	7.5400	.10463	.02340	7.5000	7.40	7.70	.30
Sand blasting	20	8.1000	.11239	.02513	8.1000	7.90	8.30	.40

Table 2: Comparative analysis of shear bond strength of recycled orthodontic brackets using ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Group Vs Shear bond strength	Between Groups	351.022	4	87.756	4198	<0.001***
	Within Groups	1.986	95	.021		
	Total	353.008	99			

Table 3: Intergroup - Comparative analysis of shear bond strength of recycled orthodontic brackets using Tukey HS

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Shear Bond Strength	Control	Flaming	5.39000*	.04572	<0.001***	5.2629	5.5171
		Ultrasonic cleaning	3.39000*	.04572	<0.001***	3.2629	3.5171
		Slow speed round carbide bur	1.75000*	.04572	<0.001***	1.6229	1.8771
		Sand blasting	1.19000*	.04572	<0.001***	1.0629	1.3171
	Flaming	Control	-5.39000*	.04572	<0.001***	-5.5171	-5.2629
		Ultrasonic cleaning	-2.00000*	.04572	<0.001***	-2.1271	-1.8729
		Slow speed round carbide bur	-3.64000*	.04572	<0.001***	-3.7671	-3.5129
		Sand blasting	-4.20000*	.04572	<0.001***	-4.3271	-4.0729
	Ultrasonic cleaning	Control	-3.39000*	.04572	<0.001***	-3.5171	-3.2629
		Flaming	2.00000*	.04572	<0.001***	1.8729	2.1271
		Slow speed round carbide bur	-1.64000*	.04572	<0.001***	-1.7671	-1.5129
		Sand blasting	-2.20000*	.04572	<0.001***	-2.3271	-2.0729
	Slow speed round carbide bur	Control	-1.75000*	.04572	<0.001***	-1.8771	-1.6229
		Flaming	3.64000*	.04572	<0.001***	3.5129	3.7671
		Ultrasonic cleaning	1.64000*	.04572	<0.001***	1.5129	1.7671
		Sand blasting	-.56000*	.04572	<0.001***	-.6871	-.4329
	Sand blasting	Control	-1.19000*	.04572	<0.001***	-1.3171	-1.0629
		Flaming	4.20000*	.04572	<0.001***	4.0729	4.3271
		Ultrasonic cleaning	2.20000*	.04572	<0.001***	2.0729	2.3271
		Slow speed round carbide bur	.56000*	.04572	<0.001***	.4329	.6871

Discussion

The success of fixed orthodontic treatment is highly dependent on reliable bracket bonding. The introduction of enamel etching by Buonocore and direct bonding systems by Newman significantly advanced bonding procedures, while preadjusted brackets have improved treatment efficiency.^{1,2} However, the high cost of these brackets necessitates cost-effective alternatives, especially in cases of accidental debonding. Recycling brackets offers a practical solution, with potential cost savings up to 90%, and the possibility of reusing brackets multiple times. Commonly employed recycling methods include direct flaming, ultrasonic cleaning, slow-speed carbide bur, and sandblasting, each with varying efficacy.¹⁵

This study evaluated and compared the shear bond strength (SBS) of recycled orthodontic brackets using the aforementioned methods against a control group of new brackets. The results revealed statistically significant differences in SBS across all groups ($p < 0.001$), with the control group showing the highest mean SBS (9.29 MPa). Among the recycled methods, sandblasting demonstrated the highest bond strength (8.10 MPa), followed by slow-speed carbide bur (7.54 MPa), ultrasonic cleaning (5.90 MPa), and direct flaming (3.90 MPa).

Sandblasting emerged as the most effective recycling method, producing bond strengths close to the clinically acceptable range of 6–8 MPa and approaching that of new brackets. This finding aligns with studies by Khanal et al. (2021), Halwai et al. (2012), Kumar et al. (2014), and Quick et al. (2005), which consistently reported high bond strength values with sandblasted brackets.¹⁶⁻¹⁹ The superior performance of sandblasting is attributed to its

ability to thoroughly clean and roughen the bracket base, enhancing mechanical retention.

In contrast, direct flaming showed the lowest SBS, indicating a significant compromise in adhesion. This finding concurs with prior reports suggesting that flaming may leave carbon residues that impede bonding unless followed by additional cleaning, such as sandblasting.^{16,19} Ultrasonic cleaning demonstrated moderate effectiveness, though its sole use may not fully eliminate adhesive remnants, consistent with the findings of Kumar et al. The slow-speed carbide bur method produced better SBS than ultrasonic cleaning and flaming but remains slightly inferior to sandblasting.¹⁸ Although effective, mechanical abrasion can risk damaging the bracket base, as noted in previous literature.

The variability in SBS among these methods reflects their differing capabilities in preserving bracket base integrity and ensuring optimal surface conditioning. Given that bond strength above 6 MPa is generally considered clinically acceptable, only sandblasting and slow-speed bur techniques achieved values close to or exceeding this threshold in the present study.¹⁹⁻²³

It is essential to recognize that bond strength in clinical practice is influenced by several factors, including bracket base design, adhesive properties, enamel surface characteristics, and operator technique. Additionally, in-vitro SBS testing using universal testing machines does not fully replicate the complex, dynamic oral environment, which includes simultaneous shear, tensile, and torsional forces. This limitation may contribute to variability in reported SBS values across studies.

While the present study confirms that sandblasting is the most efficient in-office method for recycling brackets, clinical applicability remains to be verified. Future

longitudinal in-vivo studies are recommended to assess the durability and performance of recycled brackets under functional loading conditions. Such research will be critical for establishing standardized protocols and reinforcing the clinical reliability of bracket recycling in orthodontics.

Conclusion

This study compared the shear bond strength (SBS) of orthodontic brackets recycled using four reconditioning methods—Direct Flaming, Ultrasonic Cleaning, Slow-Speed Round Carbide Bur, and Sandblasting—against a control group of new brackets. Clinically acceptable SBS values range between 6–8 MPa. Sandblasting yielded the highest SBS among recycled methods (8.10 MPa), closely matching the control group (9.29 MPa), and proving to be a reliable and cost-effective method. Direct Flaming exhibited the lowest SBS (3.90 MPa), making it unsuitable for clinical use despite its simplicity. Ultrasonic Cleaning (5.90 MPa) and Carbide Bur (7.54 MPa) showed moderate performance, with only the latter nearing clinically acceptable levels.

The findings are consistent with previous literature supporting Sandblasting as the most effective bracket recycling technique. However, this in-vitro study has limitations: it does not replicate complex oral forces, focuses solely on shear stress, and controls factors such as adhesive type and enamel morphology that may vary in clinical practice. Future in-vivo longitudinal studies are recommended to validate the clinical applicability of these results and explore combined or novel recycling techniques for improved outcomes.

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