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Effect of Adhesion Promoter on Bond Strength of Reconditioned Brackets – an *In vitro* Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author VG designed the study. Author YM performed the statistical analysis and wrote the protocol. Author SG wrote the first draft of the manuscript. Authors MG and SK managed the analyses of the study. Author SS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Objectives: To compare the shear bond strength of recycled orthodontic metal brackets using an adhesion booster and conventional primer and using the Adhesive Remnant Index (ARI) score to assess the site of debonding.

Materials and Methods: Eighty premolar teeth were randomly divided into 3 groups of 20 teeth each: Group A-New brackets and Transbond XT, Group B-Recycled brackets and Transbond XT, Group C-Recycled brackets and Transbond XT + Enhance LC. Brackets were recycled using sandblaster. Bond strength was tested on a universal testing machine and remnant adhesive on

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the tooth surface was determined. Kruskal Wallis test and Mann Whitney test were carried out to know the significant difference between the groups. Chi – square test was used to determine significant differences in the ARI (Adhesive Remnant Index) scores.

Results: Highest mean load was recorded in Group A (9.58 ± 1.72 MPa), followed by Group C (8.60 ± 2.05 MPa) and Group B (6.39 ± 1.64 MPa). Chi- square test indicated significant differences ($P = .002$) in ARI scores. Group A and Group C were associated significantly for score 2 of ARI; Group B for Score 0 of ARI.

Conclusion: The bond strength of recycled orthodontic brackets with Transbond XT was significantly lower when compared to bond strength of recycled brackets with an adhesion booster. After recycling the brackets with sandblaster and using an adhesion booster, the previously debonded brackets gave the bond strength comparable to new brackets with Transbond XT. The ARI data showed statistically significant association between the ARI scores and the groups.

Keywords: Adhesion booster; ARI; recycled brackets; sandblasting; shear bond strength; Transbond XT.

1. INTRODUCTION

Orthodontic bracket bonding has been in use for a long time and the success of fixed appliance therapy depends on the adequate bond strength and lower failure rate.

Orthodontic brackets are subjected to a large number of forces in the mouth resulting in a complex distribution of stresses within the adhesive and its junction with enamel (tooth surface) or the bracket base. The bond failure impairs the progress of the treatment and can be costly in terms of materials and time. The bond strength depends on a large number of factors including the nature of enamel surface, enamel conditioning procedures, types of adhesives used, the shape and design of bracket base as well as abuses from the patient. In such cases, an orthodontist may choose to prepare and reuse the same bracket though the bond strength may be less than new brackets.

The purpose of the present study is to compare the shear bond strength of recycled orthodontic metal brackets using an adhesion booster and conventional primer and using the Adhesive Remnant Index (ARI) score to assess the site of debonding.

2. MATERIALS AND METHODS

This in vitro study was carried out on 60 human maxillary premolar teeth that had been extracted for orthodontic/therapeutic reasons. The criteria for tooth selection included intact buccal enamel with no cracks caused by the extraction and no caries. Teeth were washed to remove any traces of blood and then stored in distilled water until the experimental procedure was initiated. The

teeth were mounted in cylindrical metal blocks using self-cure acrylic resin with the buccal surfaces aligned perpendicular to the bottom of the mold.

2.1 Materials Used in the Study Were:

1. Bonding Adhesive: Transbond XT[®] (3M Unitek, Monrovia, California, USA) (Fig. 1).
2. Adhesion Booster: Enhance LC[®] (Reliance, Itasca) (Fig. 1).
3. Brackets: MBT Premolar Brackets (Gemini[™], 3M Unitek, Monrovia, Calif, USA) (Fig. 1).
4. Curing Light: LED.D (Woodpecker, Guilin Woodpecker Medical Instrument Company Ltd, Guangxi, China.) (Fig. 1).
5. Self-polymerizing acrylic resin (pink & clear): Pink material is used to bond new brackets. Clear material is used to bond recycled brackets. (Fig. 1).
6. Elastomeric Impression Material: Speedex Putty (ISO 4823, Type 0, polysiloxane condensation-type, Coltene[®], Alstatten, Switzerland) (Fig. 1).
7. Sandblaster: Duostar Z2 (Model No: 26115, Bego, USA) (Fig. 1).
8. Thermocycler: Cold bath- Revco, Hot bath- Khere.
9. Universal Testing Machine (Model no: 9036TD, Star Testing Systems) (Fig. 2)
10. Stereomicroscope (CZM4, Labomed, USA)

2.2 Criteria for Selection of Sample

1. Non-fluorosed premolar teeth with intact buccal enamel, with no caries.
2. The teeth that were not subjected to any pretreatment with chemical or bleaching agents.

2.3 Method of Study

Sixty premolar teeth were randomly divided into 3 groups of 20 teeth each. Group A- Teeth were bonded using new brackets and Transbond XT adhesive & primer. Group B- Teeth were bonded using recycled brackets and Transbond XT adhesive & primer. Group C- Teeth were bonded using recycled brackets and Transbond XT adhesive & primer + Enhance LC.

Buccal surfaces of all the teeth were polished with a rubber cup and polishing paste for 10 seconds. The area where the bracket to be placed was etched with 37% Orthophosphoric acid for 30 seconds and washed with water and dried with compressed air for 15 seconds.

Debonded brackets were prepared by bonding brackets with composite resin Transbond XT (3 M Unitek), to unetched and slightly wet tooth surfaces. Excess bonding material was removed carefully, and the brackets were light-cured for 40 seconds (10 seconds on each of the 4 sides). The brackets were then debonded from the tooth surface with a bracket removing plier with light pressure [1,2]. A total of 40 debonded brackets were prepared. The recycling of the debonded brackets was done using Sandblaster. The debonded brackets were recycled by subjecting the bracket bases to sandblasting with Aluminum oxide particles of size 50 μm , at 5 bars of pressure for 20-40 seconds until bonding resin was no longer visible to the naked eye and the bracket base appeared frosted. Each sandblasted bracket base was then wiped with acetone on a cotton pledget and dried with an air spray [1,3].

Brackets in Group A & Group B were bonded using only Transbond XT adhesive & primer, and brackets in Group C were bonded using adhesion promoter (Enhance LC) and Transbond XT adhesive & primer. The composite used in 3 groups was kept constant as Transbond XT.

Shear bond strength was measured with a Universal Testing Machine (Model no: 9036TD, Star Testing Systems) (Fig. 2) with a 1-KN load and at a crosshead speed of 1 mm/min [4,5].

After debonding, the percentage of the surface of the bracket base covered by adhesive was determined by viewing each tooth and its

corresponding bracket with stereomicroscope at magnification power of 10x. [1,6]. The percentage of the area still covered by adhesive on the tooth was obtained by subtracting the area of adhesion covering the bracket base from 100%. Then each tooth was assigned an Adhesive remnant Index (ARI) value given by Artun and Bergland [7].

The ARI scores were used to assess the sites of bond failure on the enamel-adhesive interface and the adhesive-bracket interface. The enamel fractures after debonding are assessed with the stereomicroscope at a magnification power of 10x.



Fig. 1. Materials used in the study

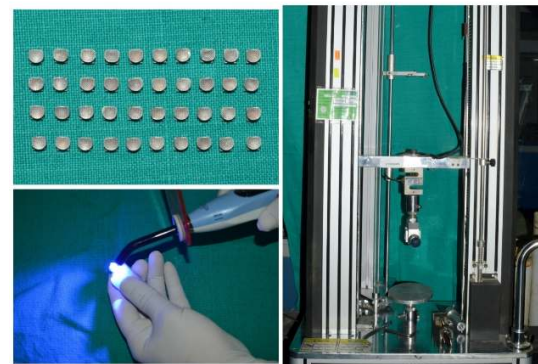


Fig. 2. Recycled brackets, Bonding of the brackets and Universal Testing Machine

2.4 Analysis of the Data

Following this procedure, the mean and standard deviation were calculated for each group for statistical evaluation of experimental data using SPSS software (Version 20.0, SPSS, Chicago). The value for significance was kept at $p < 0.05$. In order to compare the medians of the 3 groups, Kruskal Wallis test was carried out. If there was a significant difference between the groups,

pairwise comparisons using Mann – Whitney test were carried out. The chi – square test was used to determine significant differences in the ARI scores between the different groups.

3. RESULTS

The three groups tested were: Group A - New brackets bonded with Transbond XT primer & adhesive. Group B - recycled brackets bonded with Transbond XT primer & adhesive. Group C - recycled brackets bonded with Transbond XT primer & adhesive plus Enhance LC. The highest mean load is recorded in Group A (9.58±1.72 MPa) followed by Group C (8.60±2.05 MPa). Group B (6.39±1.64 MPa) recorded the lowest mean load. The Kruskal-Wallis test showed a significant difference between the groups with respect to the median load (P<0.0001) (Table 1).

To find out the significant difference between the groups, Mann-Whitney test was carried out. (Table 2) The significant difference was found between Group A and Group B (p<.0001) and Group B and Group C (p<.01). However, the difference in the median load between Group A and Group C was not statistically significant (p= .117).

3.1 Analysis of ARI Scores

Adhesive Remnant Index (ARI) showed a dissimilar pattern between these 3 groups. Pearson chi-square test was used to find out any significant association between the ARI scores and the different groups. The test indicated significant differences (P=.002) in ARI values. Group A and Group C were associated significantly with value 2 of ARI; Group B for Score 0 of ARI. Most of the failures in these

groups occurred at the adhesive-bracket interface, the exception is Group B, which showed more bond failures toward the enamel-resin interface (Table 3).

4. DISCUSSION

Bonding of orthodontic brackets has become a routine orthodontic procedure in fixed appliance therapy. A successful bracket adhesive must have an adequate shear bond strength for its continued attachment during the required clinical period. It has been suggested that bond strength values between 5.9 MPa and 7.8 MPa are sufficient for a clinically effective orthodontic bonding [8]. However, increased bond strength may be necessary when bonding to premolars and molars. Non-compliant patients, fluorosed and hypo calcified teeth, de bonded and recycled brackets also require additional bond strength.

Enhance L.C. is an adhesion promoter for specific use in orthodontics. The manufacturer recommends application with adhesive systems from its product range. The manufacturer claims that it significantly increases adhesion of resins to fluorosed, hypocalcified, or primary enamel. It is composed of hydroxyethyl methacrylate (HEMA), tetrahydrofurfuryl cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional groups, one hydrophobic and the other hydrophilic. Hydrophilic monomers in these adhesive systems help resin infiltrate enamel etched at the level of prisms. This characteristic should reduce interfacial porosity and therefore increase adhesion, achieving greater bond strength through polymerization [9,10].

Table 1. Comparison of shear bond strength of all groups tested

Group	n	Mean	SD	Min.	Median	Max.	Std. error	Kruskal-Wallis test	p value
Gp A	20	9.58	1.72	8.140	9.32	15.500	0.38		
Gp B	20	6.39	1.64	3.650	6.645	8.970	0.37	51.570	<.0001 [†]
Gp C	20	8.60	2.05	5.280	8.46	13.120	0.46		HS

[†] Highly significant (HS)

Table 2. Pair wise comparison using Mann-Whitney test

Pair	U Value	P Value
Group A vs Group B	379.5	p<0.0001 [†] (HS)
Group A vs Group C	258.5	0.117* (NS)
Group B vs Group C	84.5	p<0.01 [†] (S)

*Non-significant (NS) [†]Significant (S) [†]Highly Significant (HS)

Table 3. Analysis of adhesive remnant index scores

	N	Score 0	Score 1	Score 2	Score 3	χ²	P
Group A	20	2	3	10	5	26.07	0.002 [¶] (S)
Group B	20	11	4	4	1		
Group C	20	3	3	10	4		

[¶]Significant (S)

Debonded brackets were prepared by the method used by Chung et al. [1] and Hoogan et al. [2] to standardize the amount of composite left on the bracket mesh. The debonded brackets were recycled using sandblaster which is the most effective method of recycling. [3,11-13].

Bracket base design significantly affects mean shear bond strength [13]. In fact, the morphology of the base is an important variable for the retention of a bracket. Authors suggested that the base design may improve penetration of the adhesive material, and the size of the base has been seen to be also an important factor [14]. Wang et al found that The Tomy brackets, with its circular concave base, produced greater bond strength than did the mesh-based brackets; among the mesh-based brackets, Dentaurem, with the larger mesh size, produced greater bond strength than the brackets with smaller mesh sizes [14]. Sorel et al. evaluated the new metallic orthodontic bracket with a laser structured base and its effect on the site of bond failure and found that the laser structured base bracket's bond strength was double that of the simple foil mesh bracket but was equally safe and did not induce significant enamel detachment [15]. But same brackets are used in this study, so the base design has no influence on the results of the study. However, surface area of bracket base is taken into consideration to change SBS recorded in Newtons to Mega Pascals. Scribante et al concluded in their study that When testing brackets with anchor pylons, Transbond XT and Ortho Cem showed no significant difference between them, and both exhibited significantly higher shear bond strength values than Heliosit. When testing brackets with an 80-gauge mesh base, Transbond XT and Heliosit presented no significant difference between them, and both expressed significantly higher shear bond strength values than Ortho Cem. When testing Transbond XT and Heliosit no significant differences were found when comparing the shear bond strength of the two different bracket bases, whereas for Ortho Cem a significant reduction in bond strength values was reported when testing brackets with an 80-gauge mesh base [16]. This study shows the role of both the

adhesive and bracket base mesh in shear bond strength.

Bishara et al. [17] and Vijayakumar et al. [6] found that in general, the highest shear bond strengths were obtained after bonding new brackets. Rebonded brackets showed significantly lower and inconsistent values. This is confirmed by the present study.

Sandblasting the bracket base has been shown to increase the bond strength of new brackets to enamel by removing unfavorable oxides, contaminants on the base, and increasing surface roughness and surface bonding area [18,19]. Sandblasting of debonded brackets produced comparable bond strengths to new brackets and is considered to be the best method of recycling giving the highest shear bond strength values in recycled bracket groups [1,3]. The results of this study also showed the mean bond strength of sandblasted rebonded brackets (group B, 6.39 MPa) was significantly lower than new brackets (group A, 9.58 MPa). Algera investigated the influence of different bracket base pretreatments in relation to three different types of cement, Transbond XT, a resin composite, Fuji Ortho LC, a resin-modified glass ionomer cement (GIC), and Fuji IX Fast, a conventional glass ionomer cement, on shear as well as on the tensile bond strength. Upper incisor brackets with three types of base treatment, sandblasted, silicoated, and tin-plated, were bonded to bovine enamel and tested. They found no clear improvement in relation to the pretreatments of the bracket bases and emphasized that other factors are responsible for the resistance to fracture [20].

The results also favored the use of recycled brackets with adhesion booster. There was a significant increase in bond strength recorded with the use of recycled brackets with Transbond XT and Enhance LC than Transbond XT alone. These results are in agreement with the study done by Hoogan et al. [2] who also found an increase in bond strength of recycled brackets with Enhance LC. Newman et al. [21] also found increased bond strength of sandblasted new

brackets coated with Megabond than sandblasted new brackets without the booster. Chung et al. [1] also concluded that after sandblasting the base and application of an adhesion booster on the tooth surface, the previously debonded bracket can serve as adequately as new brackets in terms of the bond strength success.

The ARI data showed a statistically significant association between the ARI scores and the groups ($p < 0.05$). This finding was in concurrence with the previous study which showed a significant difference in ARI values and the group [6,22]. Group A and Group D were associated significantly with value 2 of ARI which showed cohesive fracture within the resin, with fracture occurring more towards the bracket – adhesive interface; and Group B for value 0 showing breakage at enamel-resin interphase. So the results from the Adhesive Remnant Index showed weak enamel-resin interface in Group B and adhesion booster increased the bond strength between enamel-resin interface. The adhesion between the resin-bracket interface in recycled brackets is already proved to be sufficiently stronger in literature.[1,6]. ARI data suggested that the increased bond strength of group D was due to the stronger resin-resin interface due to the effect of adhesion booster and sandblasting as a method of recycling produced adequate bond at bracket-resin interface.

5. CONCLUSION

This study was done to determine the effect of adding adhesion booster on the mean shear bond strength of recycled orthodontic metal brackets. The bond strength of recycled orthodontic brackets with Transbond XT was significantly lower when compared to the bond strength of recycled brackets with an adhesion booster. It was within the acceptable range though on the lower side of acceptable limits of 5.9–7.8 MPa. After recycling the brackets with the sandblaster and using an adhesion booster, the previously debonded brackets gave the bond strength comparable to new brackets with Transbond XT. So adhesion booster is recommended to be used with recycled brackets.

The ARI data showed a statistically significant association between the ARI scores and the groups. Recycled brackets without the use of adhesion booster showed weak enamel-resin interface, and use of adhesion booster with

recycled brackets increased the bond strength of enamel-resin interphase.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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