Research Article

Bond Strength Evaluation of Bonding Bases using Various Surface Treatments - An In Vitro Study

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ABSTRACT

Background: Various factors affect shear bond strength, and several methods can be used to enhance the bond strength.

Aims and Objectives: The aim of this study was to evaluate and compare the shear bond strengths after various surface treatments of bonding bases.

Materials & Methods: For this research, 275 extracted human first and second premolar teeth were cleaned and stored in artificial saliva (Saleva). The teeth were randomly divided into control and experimental groups. The groups were subdivided according to the types of brackets used (metal, ceramic and recycled metal brackets). Metal brackets (Ormco) and ceramic brackets (Ortho Organizer) were bonded on the buccal surfaces of the mounted premolars after respective surface treatments. Samples were stored in an incubator for 48 hours. The shear bond strength was evaluated using a Universal Testing Machine (UTM). Kruskal-Wallis test and Mann-Whitney U test were performed for comparison of bond strengths.

Results: Ceramic brackets showed significantly higher shear bond strength than metal brackets, with a p-value of 0.004. Within ceramic brackets, sandblasting of the tooth surface and bracket base resulted in significantly higher bond strength than other surface treatments.

Conclusion: Our study found that double primer coating and sandblasting are the surface treatments of choice to increase bond strength, and the least accepted method for the surface treatment is diamond bur grinding. Further surface studies are required to assess the effect of sandblasting on bonding bases.

KEYWORDS: Diamond bur grinding, Double primer coating, Sandblasting, Shear bond strength, Surface treatments.

INTRODUCTION

Many options for appliances to be used in orthodontic treatment are available to practitioners. Historical appliances involved banding every tooth with a metal bracket attached to the band. The development of acid etching enamel and direct bonding by Buonocore removed the need for banding every tooth, and the bonded miniature bracket, much preferred by patients, appeared in the 1960s. Patients' desire for more esthetic options has driven the development of more esthetic materials.[1]

Fixed orthodontic treatments include bonding brackets to the tooth surface for a long period. Any failure in bracket bonding during the period of treatment may lead to delay in treatment, patient discomfort, and increased cost.[2] Laboratory testing of mechanical retention indicates that adhesive-to-bracket bond strengths are less than those of equivalent-size foil/mesh metal brackets. Ceramic brackets have considerably fewer mechanical undercuts and therefore, ceramic brackets might be expected to have greater bond failure rates. Debonding is much easier with a mechanical interlock because bond strengths are apparently marginal.[3] High bond strength of the brackets is essential to withstand the orthodontic force and allow for control of tooth movement.[4] Reynold mentioned that a 5.9 to 7.8 MPa bond strength is sufficient to withstand masticatory force.[5] Bishara et al. observed mean bond strengths of 10.4 MPa and 11.8 MPa with composite resin and conventional adhesive system, respectively.[6] For economic reasons, debonded brackets are rebonded after the removal of the residual adhesive from the bases by several methods, including sandblasting, mechanical grinding, adhesive burning, and lasers.[7]

The objective of this study was to compare and assess the shear bond strength between new and recycled brackets after various surface treatments were applied to the bonding base.

MATERIALS AND METHODS

The Institutional Ethics Committee (IEC) at Seema Dental College and Hospital in Rishikesh, Department of Orthodontics and Dentofacial Orthopaedics approved this investigation. Two hundred seventy-five human premolars that had been extracted for therapeutic purposes were gathered from private dental offices and the department of oral and maxillofacial surgery at the Seema Dental College and Hospital in Rishikesh, Department of Orthodontics and Dentofacial Orthopaedics

Throughout the transit, the teeth were kept moist and free of gross debris and visible blood in a sturdy, closed container. Microbial growth can be avoided by utilising an autoclave cycle for 40 minutes and teeth were kept in artificial saliva (Saleva).[8]

Inclusion criteria:

1. Freshly extracted human premolars.
2. Maxillary premolars extracted with intact buccal surfaces.

Exclusion criteria:

1. Premolars with carious/abraded/eroded buccal surfaces.
2. Fluorosed/Hypoplastic premolar teeth.
3. Fractured / Cracked due to pressure of extraction forceps.

Distribution of the samples:

The sample collection was done by purposive sampling. The samples were divided into 6 groups, which were further divided into subgroups according to the type of brackets used, i.e. Metal, Ceramic and Recycled.

Group 1: Conventional bonding (Control group)

- Group 1 A: New metal bracket (n=25)

Group 2: Double primer coating on tooth surface

- Group 2 A: New metal bracket (n=25)
- Group 2 B: New ceramic bracket (n=25)

Group 3: Sandblasting of tooth surface

- Group 3 A: New metal bracket (n=25)
- Group 3 B: New ceramic bracket (n=25)

Group 4: Diamond bur grinding

- Group 4A: New metal bracket (n=25)
- Group 4 B: Recycled bracket (n=25)

Group 5: Sandblasting of tooth and bracket base

- Group 5 A: New metal bracket (n=25)
- Group 5 B: New ceramic bracket (n=25)
- Group 5 C: Recycled metal bracket (n=25)

Group 6: Sandblasting of bracket base of Recycled metal bracket.

- Group 6A: Recycled metal bracket (n=25)

Storage and transportation of sample:

Containers filled with artificial saliva (Saleva) were placed in the Department of Oral and Maxillofacial Surgery, Seema Dental College and Hospital and other private clinics (Figure 1). The Department of Orthodontics and Dentofacial Orthopedics received the collected samples. The teeth were kept moist and free of coarse debris and visible blood clots in a well-made airtight container during transport. A 40-minute autoclave cycle can be used to get rid of microbial development and were stored in artificial saliva.[8]

The extracted teeth were placed in an incubator for 48 hours following bonding (Figure 2).

Fig 1: Extracted teeth stored in artificial saliva

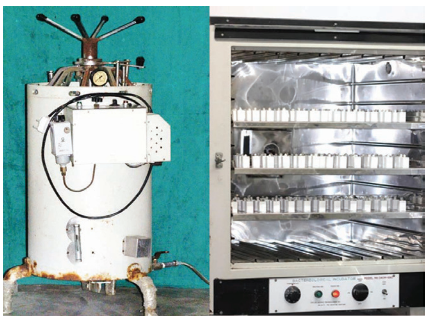

Fig 2: Laboratory autoclave and incubator containing prepared samples

Preparation of samples:

Each tooth was mounted separately in an Orthokal block (20 mm x 20 mm x 30 mm) so that the roots were fully encased in the block up to cement-enamel junction, the buccal surface of the crown was perpendicular to the block's base, and the tooth's crown was exposed for bonding (Figure 3).

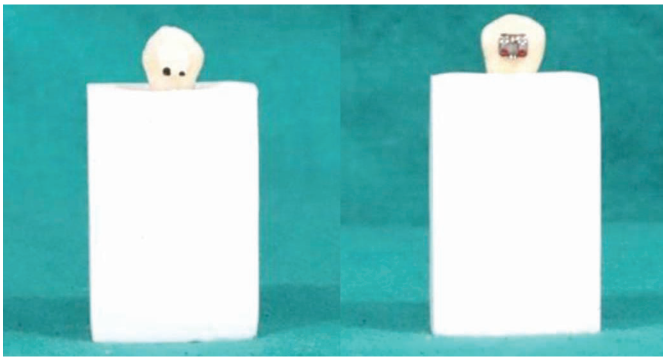

Fig 3: Prepared samples

Group 1 (Control group): The bonding surface was polished and made debris-free (Figure 4). Orthophosphoric acid (37%) was used to etch the enamel surface for 15 to 30 seconds, and the teeth were then rinsed thoroughly with water. The dull, frosty appearance of the teeth was achieved by fully drying them with an air source free of moisture and oil.

A thin coat of bonding agent (primer) was placed over the etched enamel surface after the teeth had dried fully and became frosty white. A gentle air burst that lasted for 1-2 seconds thinned the covering. With the help of a bracket holder, adhesive was applied to the back of the bonding base. The brackets were then placed, and any surplus adhesive was removed without interfering with the placement. Bonding adhesive was light cured for 10 seconds by placing the light guide as close to the bracket base as possible to get the most benefit from the light energy (Figure 5).[9]

Fig 4: Polishing of mounted tooth

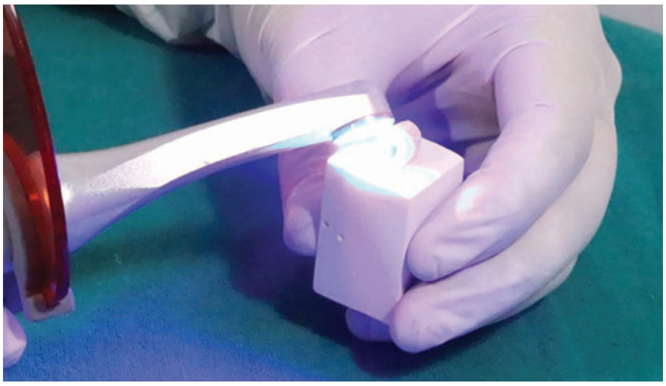

Fig 5: Bonding of bracket

Group 2- Bonding was done as Group 1 but two primer coatings were applied in Group 2.

Group 3- Tooth surface was sandblasted by 50 microns Aluminium oxide particles from 5 mm distance for 3 seconds. After sandblasting, bonding was done like Group 1.

Group 4- Grinding of the tooth surface was done by a cylindrical diamond bur. After grinding, bonding was done like Group 1.

Group 5- Sandblasting of tooth surface and bracket base was done (50 microns Aluminium oxide used for sandblasting of tooth surface from 5 mm distance for 3 seconds, 110 microns Aluminium oxide particles used for sandblasting of bracket base from 10 mm distance for 13 seconds).[10] After sandblasting, bonding was done like Group 1.

Group 6- Bonding was done like group 1. The brackets were debonded with a pin ligature cutter and lifted outward at a 45-degree angle (Figure 6). This technique is quick and gentle and leaves the brackets intact and fit for recycling. The bracket base was sandblasted using 110 microns Aluminium oxide particles, and the composite from the tooth surface was removed by finishing diamond bur. The recycled bracket was bonded again with the method mentioned above.

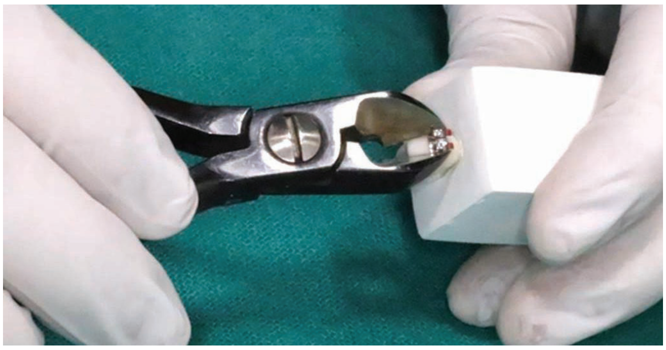

Fig 6: Debonding of bracket

Shear bond strength was measured using UTM (Universal Testing Machine). A chisel head was placed at the bracket-tooth interface, and the bracket was debonded with a crosshead speed of 1mm/min (Figure 7). The data collected from UTM was segregated according to groups and compared.

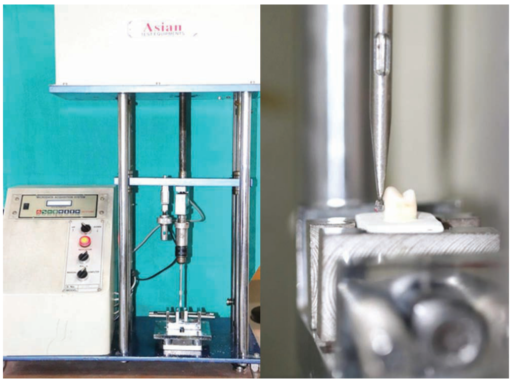

Fig 7: Debonding done by Universal Testing Machine (UTM)

RESULTS

Two hundred seventy-five extracted human premolar teeth were divided into 6 groups according to different surface treatments. For new metal brackets, the mean shear bond strength values of Group 1A, Group 2A, Group 3A, Group 4A and Group 5A were 7.46±3.27 MPa, 9.69±4.58 MPa, 9.45±6.26 MPa, 8.48±4.09 MPa and 7.22±2.43 MPa, respectively, and there was no statistically significant difference between the groups (p = 0.272). For new ceramic brackets, the mean shear bond strength values of Group 2B, Group 3B and Group 5B were 9.42±3.78 MPa, 8.41±2.78 MPa and 11.84±4.23 MPa, respectively, and there was a statistically significant difference between the groups (p = 0.004). For recycled metal brackets, the mean shear bond strength values of Group 4B, Group 5C and Group 6A were compared, which were found statistically not significant (Table 1).

Table 1- Comparison of mean shear bond strength between groups using Kruskal-Wallis test.

Sample type	Group	N	Mean (MPa)	S.D (MPa)	Min. (MPa)	Max. (MPa)	p-value
New metal bracket	1A	25	7.46	3.27	3.49	14.5	0.272
	2A	25	9.69	4.58	4.41	17.9	
	3A	25	9.45	6.26	3.93	28.69	
	4A	25	8.48	4.09	4.71	15.4	
	5A	25	7.22	2.43	4.37	13.56	
New ceramic bracket	2B	25	9.42	3.78	5.02	18.65	0.004*
	3B	25	8.41	2.78	4.63	13.5	
	5B	25	11.84	4.23	7.09	23.28	
Recycled metal bracket	4B	25	7.89	2.50	5.26	13.56	0.26
	5C	25	7.92	3.81	3.81	18.82	
	6A	25	8.74	2.82	5.15	16.5	

*Statistically significant p-value

In Table 2, the mean shear bond strength values of new ceramic brackets of Group 2B and Group 3B were compared with those of Group 5B using the Mann-Whitney U test, which was found to be statistically significant.

Table 1- Comparison of mean shear bond strength between groups using Kruskal-Wallis test.

Sample type	Group	Mean (MPa)	S. D (MPa)	Z value	p-value
New ceramic bracket	2B	9.42	3.78	-2.223	0.026*
	5B	11.84	4.23		
New ceramic bracket	3B	8.41	2.78	-3.272	0.001*
	5B	11.84	4.23		

*Statistically significant p-value

DISCUSSION

The purpose of this study was to evaluate and compare the shear bond strength of bonding bases after various surface treatments between six groups. This will help to minimize breakages and faster treatment results, as bond strength must be able to withstand masticatory forces.

In this study, we used surface treatment methods which can be done easily at chairside. The samples were randomly divided into 6 groups based on different surface treatments - Group 1 (Conventional bonding), Group 2 (Double primer coating), Group 3 (Sandblasting of tooth surface), Group 4 (Diamond bur grinding), Group 5 (Sandblasting of tooth surface and bracket base) and Group 6 (Sandblasting of recycled bracket base) which were further divided into subgroups of new metal brackets, Ceramic brackets and recycled metal brackets, respectively.

In new metal brackets, there was no statistically significant difference in shear bond strength when their mean values were compared in different subgroups. However, in ceramic brackets, when shear bond strengths of Group 2B, Group 3B and Group 5B were compared, the bond strength was found to be statistically significant (p=0.004). In recycled brackets, bond strength was almost equal to the control group and was found to be statistically not significant.

The bond strength mean values of new metal brackets were nearly equal to the control group mean values, but when compared to new ceramic brackets, the bond strength mean values were found to be highly significant (p=0.004). When compared to recycled metal brackets, they were almost similar and not significant (p=0.26), suggesting an increase in bond strength mean values in ceramic bracket groups. Ceramic brackets had significantly superior mean shear bond strength values than metal brackets. This finding is in agreement with earlier studies.[11,12,13]

New metal brackets:

It was observed that the mean shear bond strengths of Group 1A, Group 2A, Group 3A, Group 4A and Group 5A were 7.46±3.27 MPa, 9.69±4.58 MPa, 9.45±6.26 MPa, 8.48±4.09 MPa and 7.22±2.43 MPa, respectively. Hence, the maximum bond strength was found in Group 2A (double primer coating), and the minimum shear bond strength was found in Group 5A (Sandblasting of the tooth surface and bracket base). The mean difference in above mentioned groups was found statistically not significant.

The order of mean shear bond strength values of new metal brackets with various surface treatments was:

Double primer Coating (9.69±4.58 MPa) > Sandblasting Tooth surface (9.45±6.26 MPa) > Diamond bur grinding (8.48±4.09 MPa) > Conventional bonding (7.46±3.27 MPa) > Sandblasting Tooth surface and Bracket base (7.22±2.43 MPa)

New ceramic brackets:

It was observed that the mean shear bond strengths of Group 2B, Group 3B and Group 5B were 9.42±3.78 MPa, 8.41±2.78 MPa and 11.84±4.23 MPa, respectively. Hence, the maximum shear bond strength was found in Group 5B (Sandblasting of tooth surface and bracket base) and the minimum was found in Group 3B (Sandblasting of tooth surface). The mean difference between above mentioned groups was statistically significant.

The order of mean shear bond strength values of new ceramic brackets with various surface treatments was:

Sandblasting Tooth surface and Bracket base (11.84±4.23 MPa) > Double primer coating (9.42±3.78 MPa) > Sandblasting Tooth surface (8.41±2.78 MPa)

Recycled metal brackets:

It was observed that the mean shear bond strengths of Group 4B, Group 5C and Group 6A were 7.89±2.50 MPa, 7.92±3.81 MPa and 8.74±2.82 MPa respectively. Hence, the maximum shear bond strength was found in Group 6A (Sandblasting of tooth surface), and the minimum was found in Group 4B (Diamond bur grinding). The mean difference in above mentioned groups was found to be statistically not significant.

The order of mean shear bond strength values for new ceramic brackets with various surface treatments was:

Sandblasting Bracket base (8.74±2.82 MPa) > Sandblasting Tooth surface and Bracket base (7.92±3.81 MPa) > Diamond bur grinding (7.89±2.50 MPa)

In contrast to the present study, according to a recent study[14], using burs for recycling orthodontic brackets, found to provide a medium bond strength in comparison to other methods. But sandblasting was not recommended because of its low bond strength. The values of bond strength between the bracket and enamel decreased after the debonding and rebonding process.[14] Further surface studies are required to assess the effect of sandblasting on bonding bases and enamel abrasion assessment.

CONCLUSIONS

The following conclusions can be drawn from the present study:

1. The shear bond strength values of ceramic brackets were higher than those of metal brackets.
2. The order of shear bond strength values in new metal brackets with various surface treatments was:

   Double primer Coating > Sandblasting Tooth surface > Diamond bur grinding > Conventional bonding > Sandblasting Tooth surface and Bracket base

3. The order of shear bond strength values in new ceramic brackets after various surface treatments was:

   Sandblasting Tooth surface and Bracket base > Double primer coating > Sandblasting Tooth surface

4. The order shear bond strength values in recycled metal brackets after various surface treatments was:

   Sandblasting Bracket base > Sandblasting Tooth surface and Bracket base > Diamond bur grinding

Sandblasting of tooth surface and bracket base showed maximum shear bond strength value in ceramic brackets while minimum in new metal brackets.

Hence, it was found in our study that double primer coating and sandblasting are surface treatment of choice to increase bond strength and least accepted method for the surface treatment is diamond bur grinding.

Source of Funding

None.

Conflicts of Interest

There are no conflicts of interest.

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