International Journal of Dental Research
www.dentaljournal.net
Online ISSN: 2664-9055, Print ISSN: 2664-9047
Received: 01-06-2023, Accepted: 16-06-2023, Published: 03-07-2023
Volume 5, Issue 3, 2023, Page No. 6-10

A comparative evaluation of the effect of different recycling methods on the tensile bond strength of metal brackets

Dr. Vaibhavi Finavkar[1*], Dr. Kamlesh Garg[2], Dr. Bhavesh Kothari[3], Dr Khyati Agarwal[1], Dr Harshita Agarwal[1]
[1] PG Student, Department of orthodontics, Pacific Dental College & hospital, Udaipur, Rajasthan, India
[2] Professor and Head, Department of orthodontics, Pacific Dental college & hospital, Udaipur, Rajasthan, India
[3] Professor, Department of orthodontics, Pacific Dental College & hospital, Udaipur, Rajasthan, India

Abstract
Aim: To evaluate and compare the effect of different recycling methods on the tensile bond strength of metal brackets.
Materials and method: In this study, 52 new metal brackets were bonded to the premolar teeth and were later divided into 4 groups. Group I, II, III were the experimental groups wherein the brackets were debonded and recycled using 3 different methods: (I) using burning method, (II) using burning + sandblasting method, (III) using burning + sandblasting + silane coupling agent application. Group IV was the control group. The recycled brackets were rebonded, and final debonding of all the brackets including the control group brackets was performed using universal testing machine at the cross-head speed of 1mm/min and the tensile bond strength was determined.
Results: The highest tensile bond strength was obtained with Group IV (8.62±2.80 MPa), followed by Group II (8.58±1.41 Mpa) and Group III (7.83±1.10 MPa), and the least value was obtained with Group I (7.30±1.39).
Conclusion: Tensile bond strength of new brackets was higher than the recycled brackets. Among recycled brackets, burning + sandblasting method provided almost comparable tensile bond strength to the new brackets. Burning + sandblasting + silane coupling agent application provided a borderline value of bond strength for clinical use, while burning method alone led to a significantly lower bond strength value.

Keywords: Burning, sandblasting, silane coupling agent, tensile bond strength

Introduction
Accidental dislodgment of an orthodontic bracket, due to occlusal trauma or intentional removal in order to reposition it to achieve ideal treatment goals, are common occurrences in the orthodontic treatment [1]. When rebonding a bracket during treatment the operator is faced with the choice of rebonding the same bracket or using a new one. Using a new bracket each time will increase the cost of providing treatment, particularly if brackets are purchased in single kit per patient, as using a new bracket means breaking into a new kit. In case of rebonding the same bracket, aggregations of adhesive such as may occur on the bracket base, need to be removed in order to allow correct seating of the bracket. Such adhesive removal may be performed by hand sealers or mechanical instruments or some simple chair-side recycling procedures. Rebonding the old bracket can reduce the waste and cost for both the orthodontists and the patients [2].

A variety of thermal methods such as direct flaming or heating in a furnace are used in clinics for recycling orthodontic brackets. Micromechanical bonding systems, such as sandblasting with aluminum oxide particles that create a very fine roughness, increase the surface area, thereby enhancing mechanical and chemical bonding are also used for recycling the failed brackets. Moreover, advances in silane coupling agents contribute to high bond strength by promoting a chemical bond between resin composite, ceramic (silica based) and metal (base metal). It has been reported that application of a silane agent to base metal and silica-based ceramic surfaces after sandblasting with aluminum oxide particles produces higher bond strengths [3]. All this methods can be performed in-office without the need for sending brackets to laboratory such as done in commercial recycling. Thus, the chair-side recycling procedures are not only convenient to the orthodontists but they are also time saving.

An ideal outcome of bonding recycled brackets to the tooth surface should result in an attachment that is strong enough to endure the forces of orthodontic treatment and mastication without dislodgement, while at the same time be safe enough to avoid damage to the surface during debonding following the end of the treatment. According to I. R. Reynolds, the desired tensile bond strength of metal brackets to tooth structure required to carry out orthodontic treatment is said to be approximately 6 MPa–8 MPa [4]. The type of the recycling procedure used has direct influence on the bond strength of brackets.

Here, in this study three different recycling methods are used to determine a simple and effective method for chairside reconditioning of metal orthodontic brackets and to determine a method of reconditioning which exhibits best tensile bond strength.

Materials and method
The study sample composed of 52 extracted premolars with intact enamel surfaces having no cracks caused by the extraction forceps or any developmental defects, no pre-treatment with any chemical agents such as formalin or hydrogen peroxide and the teeth that were non-carious and extracted for orthodontic purpose.

The collected teeth were then stored in 0.1% thymol solution for 3 weeks for disinfecting the extracted teeth.

Teeth were then rinsed and stored in artificial saliva solution at room temperature until use. The teeth were then embedded into cold cure acrylic resin (DPI, India). Cubes of cold cure acrylic resin were prepared of size 1.5X1.5 cm (Figure I). The teeth were oriented in such a way that their labial surface would be parallel to the force during the tensile bond test. The enamel surface was projected 1mm above the level of the resin. The teeth were mounted in different colors according to the group they were in: red for Group I, green for Group II, blue for Group III and clear acrylic for Group IV. The buccal surface of the teeth was cleaned and polished with a non-fluoridated pumice slurry and dental polishing brush for 10 seconds.

52 new premolar metal brackets (ORMCO, US) with 0.022x0.028” slot MBT prescription (Figure II) were used in this study. These brackets were bonded to the prepared tooth surface. Firstly, etching of the enamel surface using 37% phosphoric acid gel (Actino Gel, USA) for 30 seconds was carried out. After that the etchant was washed off with running tap water for 10 seconds and then the tooth surface was air dried. The etched enamel showed matte, dull whitish and lightly frosted appearance. Following which a thin layer of Bonding Agent (Orthosolo, ORMCO, US) was applied to the etched enamel surface, which was then light cured for 15 seconds using visible light curing unit. Then metal brackets (ORMCO, US) were held by bracket holding plier and adequate quantity of composite resin (ENLIGHT light cure adhesive, ORMCO, US) was applied on the bracket base, the brackets (ORMCO, US) were then placed on the prepared tooth surface and firmly pressed into position. Excess adhesive was then removed carefully, using dental explorer, and the brackets were light-cured for 20 seconds using Visible Light Curing Unit.

The bonded brackets were then separated from the tooth surface by using bracket removing plier. After debonding, the tooth surfaces were reconditioned for rebonding by cleaning the tooth surface using airotor handpiece and finishing bur until no adhesive remained on the surface. The debonded brackets were subjected to different recycling methods.

Group I: In this group, the base of the metal brackets was flamed using Piezo gas burner (Thermo gas torch, temperature: 1200℃) until they turned cherry red, so as to burn off the residual composite resin from the bracket base. The brackets were then quenched in water at room temperature, following which the residual composite resin can be easily removed by lightly scraping the residue. The brackets were then air dried.

Group II: In this group the base of the metal brackets was flamed and then sandblasted using a sandblaster. In this sandblaster, aluminium oxide particles (Al_2O_3, 50 µm) were blased at a distance of 10 mm under 9 bars of pressure for 30 seconds.

Group III: In this group the base of the metal brackets was flamed, then sandblasted followed by which a thin layer of silane couping agent (3-methacryloxypropyltrimethoxsilane) (Angelus, Brazil) was applied and then was allowed to dry for 5 minutes.

Group IV: In this group (Control) the teeth were bonded on the etched enamel surface with new metal brackets.

Then all the recycled metal brackets were bonded on the teeth again. The bonding procedures were carried out by the same operator.

All the brackets were then debonded using Universal Testing Machine to evaluate the tensile bond strength. The acrylic blocks were placed on a universal joint to ensure that the applied force was parallel to the tooth surface. The stainless steel ligature tie was used as a harness to connect the bracket wings with the movable crosshead. Tensile force was applied with a crosshead speed of 1mm per minute.

Later, data collected in the present study was compiled in Microsoft excel sheet. Mean standard deviation of all parameters mentioned in the study were calculated for all the groups. The one-way ANOVA test and Student’s T test were used to compare the tensile bond strength of all groups and within the groups.

Fig 1: Burning method

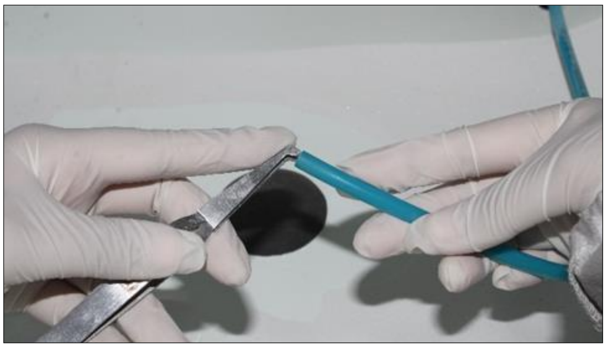

Fig 2: Sandblasting method

Fig 3(a): Silane coupling agent

Fig 3(b): Application of silane coupling agent to bracket base

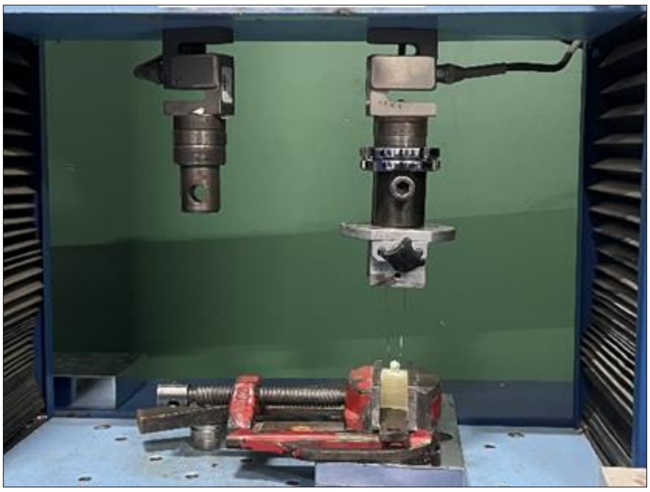

Fig 4: Universal testing machine

Results

The results were based on the tensile bond strength achieved in MPa in all the experimental and control groups.

Table I represents mean value and standard deviation of Tensile bond strength of recycled metal brackets of all the experimental groups (Group I, II, III) and control group (Group IV). The highest tensile bond strength was observed in Group IV (8.62±2.80) followed by Group II (8.58±1.41), Group III (7.83±1.10) and the least amount of tensile bond strength was observed in Group I (7.30±1.39).

Table II represents the comparison of tensile bond strength of Group I, II and III with Group IV. There was a statistically insignificant difference between the experimental groups and the control group. This table suggests that the tensile bond strength of Group II brackets is comparable to the brackets of the control group as the mean difference between this groups is minimum (-0.035), followed by tensile bond strength of Group III brackets (-0.785) and the highest mean difference was observed when the control group was compared with Group I (-1.320), showing the least tensile bond strength when compared to the control group.

Table III represents the multiple comparison between all the groups. There was statistically significant difference between Group I v/s Group II. ($p < 0.05$).

Table 1: Mean value and standard deviation of tensile bond strength of recycled metal brackets of all the experimental groups (Group I, II, III) and control group (Group IV).

Group	Sample (n)	Mean TBS (Mpa)	Standard deviation (SD)
Group I	13	7.30	1.39
Group II	13	8.58	1.41
Group III	13	7.83	1.10
Group IV	13	8.62	2.80

Table 2: Comparison of tensile bond strength of experimental groups (Group I, II, III) with the control group (Group IV).

Group	Mean Difference	p value
Group IV vs Group I	-1.320	0.140
Group IV vs Group II	-0.035	0.969
Group IV vs Group III	-0.785	0.356

Table 3: Intergroup comparison of tensile bond strength of all the groups.

Group	Mean difference TBS (Mpa)	p value
Group I vs Group II	-1.285	0.028**
Group I vs Group III	-0.535	0.286
Group I vs Group IV	-1.320	0.140
Group II vs Group III	0.750	0.143
Group II vs Group IV	-0.035	0.969
Group III vs Group IV	-0.785	0.356

**p value <0.05 indicates highly significant association

Discussion

Metal brackets are widely used for the orthodontic treatment. Despite the progress achieved in adhesion of orthodontic brackets to tooth surface, bracket detachment is still a common undesirable experience for most orthodontists. Bracket failure is usually caused by the application of inappropriate masticatory forces or because of poor bonding technique, but sometimes the clinician decides to intentionally detach one or more brackets and reposition them in order to obtain a proper tooth position [5]. The present study was done to determine the tensile bond strength of rebonded metal brackets using various recycling procedures. The bonding and testing procedures were carried out by the same operator to minimize technique inconsistencies. Bovine teeth have been used in several *in-vitro* studies. However, the bond strength measurements for bovine teeth have been found to differ from that of human substrate. Many authors have explored whether there are differences in bond strength of human versus bovine teeth. Ruttermann et al in a study concluded that shear bond strength test on bovine teeth gives different quantitative results compared to human substrate. Thus, bovine teeth can only partly be recommended as a substitute for human teeth [6].

Therefore, in the current study human extracted teeth were used. Disinfection of extracted teeth is essential to avoid cross infection during laboratory or research procedures. However, the choice of the disinfecting agent must be based on its capacity of not altering dental structures or their reactions when submitted to experimental studies [7]. Alireza Borouziniat et al in a study concluded that the storage of the teeth in Thymol had no significant effect on the shear bond strength of composite. According to him, thymol is a good solution for storing teeth for more than 6-month [8]. Thus, in our study the teeth were cleaned and stored in 0.1% thymol solution. The stored teeth were then divided into four groups, three experimental group and one control group. The brackets of experimental group were recycled using different methods (Group I – Burning, Group II – Burning + Sandblasting, Group III – Burning + Sandblasting + Silane coupling agent application) and bonded on the extracted premolar teeth. Tensile and shear bond strength test are valid test for studying orthodontic bonding. As most of the studies conducted in past are related to shear bond strength estimation, our present study aimed to compare the tensile bond strength of new and recycled metal brackets, which was subjected for recycling using three different methods. Different crosshead speeds of the Instron machine may influence the tensile bond strength. In this study, a crosshead speed of 1 mm/min was used to record the tensile bond strength.

In the current study we found that maximum tensile bond strength was in Group IV (Control Group) i.e. 8.62Mpa, followed by Group II (Burning + Sandblasting) i.e. 8.58Mpa, Group III (Burning + Sandblasting + Silane coupling agent application) i.e. 7.83Mpa and Group I (Burning) i.e.7.30Mpa. The minimum tensile bond strength was found in Group I (7.30Mpa) brackets which were recycled using the burning method.

Quick et al [9] compared the shear peel bond strength of metal brackets recycled by burning method with the newly bonded brackets. They found that flamed brackets showed very low bond strengths (2.71 Mpa), which significantly differed from the newly bonded brackets (7.78 Mpa). The results of their study is comparable to our study, as in our study the tensile bond strength of burning group (Group I) is minimum (7.30Mpa). This decrease in bond strength might be because the metal is softened by the heating process, which makes it more vulnerable to masticatory damage. Another disadvantage of burning off the composite is that the bracket discolours, unless it is electropolished afterwards. Mirhashemi et al [10] compared the bond strength of newly bonded brackets with the brackets that were recycled by burning and sandblasting method. The results showed that lowest bond strength was noted in the burning group (6.32Mpa). The result of this study was comparable to our study. This may be because in direct flaming method, removal of the acrylic-bonding agent is the most critical part of the recycling process as it requires long exposure to heat. Exposure to heat may lead to stress relieving or softening of cold worked metal along with decreasing corrosion resistance. Chacko et al [11] conducted a study to compare the bond strength of recycled metal brackets (sandblasting, thermal method, adhesive grinding by tungsten carbide bur, and Er: YAG laser method) with the newly bonded metal brackets. The results showed that the mean bond strength of the thermal method was low (4.44 Mpa). The result of this study were also comparable to our study. Moreover, the thermal treatment may produce a layer of metal oxide, which is removed by electropolishing, leading to a possible slot widening in the bracket and a reduction in mesh strand diameter loss of the metal.

I.R. Reynolds (1976) [4] suggested that the desired tensile bond strength for metal brackets to the tooth structure required to carry out orthodontic treatment is 6Mpa-8Mpa. In our study, Group I showed the lowest tensile bond strength (7.30 Mpa). Although it is low, the tensile bond strength is within the acceptable limits to be used clinically.

In Group II, where the brackets were recycled using burning + sandblasting method has maximum tensile bond strength (8.58Mpa) as compared to other experimental groups. Thus, this method can be used clinically. The brackets were recycled by sandblasting 50μm aluminum oxide (Al_2O_3) particles with a sandblaster under 9 bars of pressure for 30 seconds.

Chetan et al [12]. conducted a study to compare the bond strength of brackets recycled by four different methods (1) roughened with green stone, (2) direct flamed, (3) flamed followed by ultrasonically cleaned, (4) sandblasted to that of the newly bonded brackets. Sandblasting method showed the highest bond strength among the experimental groups. The mean bond strength of brackets recycled by sandblasting method was 7.44Mpa while that of the newly bonded brackets was 8.45 Mpa. The results of this study agrees with our study. This might be because sandblasting increases micromechanical bonding and result in improved retention between alloy and resin by cleaning oxides or greasy materials from the metal surface. Bahnasi et al. (2013) [13] conducted a study to compare the bond strength of metal brackets recycled by sandblasting method to the newly bonded metal brackets. The results showed that the mean bond strength of brackets recycled by sandblasting method was 8.77Mpa which was mathematically lesser when compared to the newly bonded brackets, which was 9.15Mpa. However, both the bond strengths were very much comparable. This study concluded that sandblasted recycled orthodontic brackets can be used as an alternative to new brackets. This results are in agreement with our study. Aksu et al (2013) [14] in a study has used two different bracket base cleaning procedures 1) Sandblasting and 2) Carbide bur cleaning and evaluated their effect on bond strength, their study concluded that bond strength of rebonded brackets after sandblasting was not significantly different than of new brackets. The mean shear bond strength of the new brackets was 9.6 ± 2.7 MPa. While the mean bond strength of brackets recycled by sandblasting was 10.8 ± 2.9 Mpa. This might be because sandblasting may increase the retention of the brackets. Sandblasting not only removes the remaining adhesive but it might also roughen the metal surface, increasing the surface area to allow better bonding [13]. This results differ from our study as here the bond strength of recycled brackets was more than that of the newly bonded brackets. This difference might be because of the use of air abrasion alone for recycling, while in our study firstly the bracket base was flamed and then sandblasted.

In Group III, the brackets were recycled using (Burning + Sandblasting + Silane coupling agent application) showed acceptable tensile bond (7.83Mpa) strength which can be clinically used.

In orthodontic literature, bonding brackets to enamel is well documented. Nevertheless, the influence of silane treatment of stainless steel brackets has not been sufficiently investigated. A silane-coupling agent can connect silicon dioxide groups on activated metal or ceramic surfaces with an adhesive consisting of a methyl-methacrylate or a 2,2-bis [p-(3- methacryloxy-2-hydroxypropoxy) -phenyl] propane system because of its bipolar structure [31]. Faltermeier et al [15] conducted a study to compare the effect of a silicoating system, the influence of sandblasting, and the effect of a silane-coupling agent after sandblasting on the shear bond strength of stainless steel foil-mesh brackets. The results showed that after sandblasting, there was a significant increase of SBS (7.43 Mpa) as compared with the control group (5.86 Mpa). The use of a silane-coupling agent after sandblasting showed a significant enhancement of SBS (7.42 Mpa) compared with the untreated brackets (control group). However, silane-coupling agent after sandblasting did not change the SBS significantly when compared with the sandblasted brackets [15]. This results were different from what we obtained in our study. This might be because in this study, an artificial oral environment with a mastication device was used to simulate moisture and temperature changes in the oral cavity while our study was performed in dry environment. In our study, the mean tensile bond strength of Group III brackets was (7.83±1.10) which was less as compared to the mean tensile bond strength of Group IV (8.62±2.80) and Group II (8.58±1.41) brackets. However, the mean tensile bond strength difference of Group III brackets was statistically insignificant. Atsü et al [3] evaluated the effect of tribochemical silica coating and silane surface conditioning on the bond strength of metal and ceramic brackets bonded to enamel surfaces with light-cured composite resin. The results showed higher bond strengths in both metal and ceramic brackets after silica coating followed by silanization. This results were not equivalent to our study.

In our study, the mean tensile bond strength achieved in Group IV (newly bonded brackets) was 8.62 MPa. This results were comparable to many previous studies. The mechanical retention achieved with the new brackets is more as its base consists of many cross shaped structures connected to each other. The cross and the spaces between them provide an extensive surface area for the adhesive to achieve adequate bonding.

Conclusion

The following conclusion is drawn from the present study:

Group II (Burning + Sandblasting) is the best method for recycling the metal brackets, as it provides highest *in-vitro* tensile bond strength.

Group III (Burning + Sandblasting + Silane coupling agent application) recycled brackets has clinically acceptable tensile bond strength. Hence, this method can also be used for recycling metal brackets.

Group I (Burning) this method did not produce acceptable *in-vitro* tensile bond strength. Hence, this method cannot be used for clinically recycling metal brackets.

In our study, we found highest tensile bond strength in Group IV (8.62 Mpa) followed by Group II (8.58Mpa) and Group III (7.83 Mpa) respectively.

References

1. Bansal N, Valiathan A, Bansal K. The effects of various in-office reconditioning methods on shear bond strength, morphology of slots and bases of stainless brackets: an *in vitro* study. Journal of Indian Orthodontic Society,2011:45(4):175-82.
2. Regan D, LeMasney B, Noort RV. The tensile bond strength of new and rebonded stainless steel orthodontic brackets. The European Journal of Orthodontics,1993:15(2):125-35.
3. Atsü S, KeskIn Y. Effect of silica coating and silane surface treatment on the bond strength of soft denture liner to denture base material. Journal of Applied Oral Science,2013:21:300-6.
4. Alzainal AH, Majud AS, Al Ani AM, Mageet AO. Orthodontic bonding: review of the literature. International Journal of Dentistry, 2020, 14.
5. Ahrari F, Basafa M, Fekrazad R, Mokarram M, Akbari M. The efficacy of Er, Cr: YSGG laser in reconditioning of metallic orthodontic brackets. Photomedicine and laser surgery,2012:30(1):41-6.
6. Rüttermann S, Braun A, Janda R. Shear bond strength and fracture analysis of human vs. bovine teeth. PLoS One,2013:8(3):e59181.
7. Moura JS, Rodrigues LK, Del Bel Cury AA, Lima EM, Garcia RM. Influence of storage solution on enamel demineralization submitted to pH cycling. Journal of Applied Oral Science,2004:12:205-8.
8. Jarahi N, Borouziniat A, Jarahi L, Nejat AH. Effect of different storage solutions and autoclaving on shear bond strength of composite to dentin. J Res Med Dent Sci,2018:6:50-3.
9. Quick AN, Harris AM, Joseph VP. Office reconditioning of stainless steel orthodontic attachments. The European Journal of Orthodontics,2005:27(3):231-6.
10. Mirhashemi AH, Hosseini MH, Chiniforoush N, Soudi A, Moradi M. Shear bond strength of rebonded ceramic brackets using four different methods of adhesive removal. Journal of Dentistry (Tehran, Iran),2018:15(1):54.
11. Chacko PK, Kodoth J, John J, Kumar K. Recycling stainless steel orthodontic brackets with Er: YAG laser-An environmental scanning electron microscope and shear bond strength study. J Orthod Sci,2013:2(3):87-94.
12. Chetan GB, Reddy M. Comparative evaluation of four office reconditioning methods for orthodontic stainless steel brackets on shear bond strength—an *in vitro* study. Ann Essences Dent,2011:3(1):6-13.
13. Bahnasi FI, Abd Rahman AN, Abu Hassan MI. Effects of recycling and bonding agent application on bond strength of stainless steel orthodontic brackets. Journal of clinical and experimental dentistry,2013:5(4):197.
14. Aksu M, Kocadereli I. Influence of two different bracket base cleaning procedures on shear bond strength reliability.
15. Faltermeier A, Behr M. Effect of bracket base conditioning. American journal of orthodontics and dentofacial orthopedics,2009:135(1):12-e1.