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Effect of different surface treatment with panaviaV5 on shear bond strength of metal brackets to silver amalgam

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ABSTRACT

Background: This study was conducted to compare the shear bond strength (SBS) of orthodontic brackets to amalgam surfaces by two surface treatment methods, two different adhesives, and one intermediate resin and also to evaluate surface roughness after two preparation methods as well as bond failure mode.

Materials and Methods: In this *in-vitro* study forty-eight amalgam samples were randomly allocated to four groups. In Groups 1–3, specimens were sandblasted with 50 μm aluminum oxide, followed by application of Alloy primer in Groups 1 and 2. In Group 3 Alloy primer had not used. In Group 4, samples were prepared by silica coating using a silane coupling agent. Surface roughness analysis was performed in 10 additional samples after two surface treatments. The brackets in Group 1 were bonded with Transbond XT and those in other groups were bonded with Panavia V5. All specimens were examined for SBS following 5000 times thermocycling at 5°C–50°C. Modified adhesive remnant index was utilized for the bond failure mode. Data analysis was done by one-way analysis of variance, *post hoc* Tukey, Kruskal–Walli and Mann–Whitney U tests. Statistical significance was set at $P < 0.05$.

Results: The findings indicated the mean SBS were low (ranged from 0.19 to 4.66 MPa) and significantly lower in Group 3 than in Group 4 ($P = 0.009$). Bond failure occurred in adhesive/amalgam interface in nearly all samples. Silica coating produced significantly lower roughness than sandblast ($P = 0.009$).

Conclusion: Silica coating had a significant higher bond strength than sandblast without application of Alloy primer. However compared to sandblast with Alloy primer, silica coating did not significantly improve the bond strength. Chemical bond between PanaviaV5 and sandblasted amalgam was not considerable.

Key Words: Dental amalgam, orthodontic brackets, Panavia, shear strength

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INTRODUCTION

Development of bonding techniques in orthodontics has reduced the banding of posterior teeth. The use of bands can increase the risk of dental caries and periodontal diseases due to dental plaque accumulation.[1] Some orthodontic patients, particularly young adults, have been reported to have

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amalgam restorations on the buccal surface of their posterior teeth. In such cases, an important clinical challenge ahead of orthodontists is reliable bonding of orthodontic brackets to amalgam restorations.[2] Several investigations have addressed this clinical problem and introduced different procedures for improving bonding to silver amalgam. Techniques that have been reported include surface treatments, metal bonding adhesives, and different intermediate resins. Many studies have recommended intraoral sandblasting for metal surface roughening, which increases the bonding strength by creating scratch-like irregularities.[3,4] Other surface preparation methods like diamond bur roughening, chemical corrosion, application of Ga-Sn liquid, and tribochemical silica coating have been proposed to improve the bonding strength to nonenamel surfaces.[4-7]

The tribochemical silica-coating is a technique for abrasion of metal or ceramic surfaces with 30 μm grain size silica-modified aluminum oxide. The silica particles are embedded into the surface by blasting pressure, developing both a chemically active surface to resin via a silane coupling agent and ultrafine mechanical retention by sandblasting. Silica coating is being used in many dental applications such as intraoral ceramic repair involving metal exposure and amalgam repair with resin composite.[8-10]

Metal bonding adhesives like 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), BIS-GMA resins, or resins containing 4-methacryloxyethyl trimellitate anhydride have an advantage of chemical adhesion to amalgam surfaces.[3,6,7] Panavia is a BIS-GMA resin containing 10-MDP for whose bonding mechanism both chemical bonding to metal oxides and mechanical retention to irregularities have been reported[6,11] and Panavia V5 is the latest version of this cement. Alloy primer containing 10-MDP has been proposed as a bonding agent for metal surfaces and recommended for bonding with Panavia V5 according to manufacturer instructions.

This *in vitro* study was primarily aimed to compare the shear bond strength (SBS) of metal brackets to silver amalgam using two adhesives (PanaviaV5 [Kuraray Noritake Dental Inc., Okayama, Japan] and Transbond XT [3M Uniteck, Monrovia, California, USA]), two different surface treatments (sandblasting vs. silica coating), and one intermediate resin (Alloy primer [Kuraray Noritake Dental Inc., Okayama, Japan]) and also to assess the bond failure by the adhesive remnant index (ARI). The secondary aim was to compare the surface roughness of the two surface preparation methods and to perform a scanning electron microscope (SEM) analysis of the nature of interfacial failure. It was hypothesized that there would be no statistically significant difference among various bonding procedures in terms of the bond strengths.

MATERIALS AND METHODS

Amalgam specimens

In this *in-vitro* study fifty eight cylindrical amalgam specimens (length of 8 mm and cross-sectional diameter of 3 mm) were prepared by condensing a lathe-cut non-gamma 2 amalgam, ANA 2000 (Nordiska Dental AB, Angelholm, Sweden) and polished by manual tools. The samples were burnished with brown and green rubber points after 24 h (Shofu Inc., Kyoto, Japan).

Surface conditioning methods

The amalgam samples were randomly allocated to four groups. Each group contained 12 samples. According to the manufacturers' instructions, the study groups received the following surface preparations:

Groups 1 and 2: Air abrasion with 50 μm Al_2O_3 for 3 s in a microetcher (Simed srl, Branzate, Italy) at air pressure of about 7 kg/cm^2 from a distance of 10 mm, followed by Alloy primer application (AP: Kuraray Noritake Dental Inc. Okayama, Japan).

Group 3: Air-borne particle abrasion the same as the former groups without the use of intermediate resin (AP).

Group 4: Silica coating with 30 μm SiO_2-modified Al_2O_3 particles for 15 s (Rocatec Soft, 3M ESPE, Seefeld, Germany) using Rocatec junior (3M ESPE, Seefeld, Germany) at 2.8 bar pressure from a distance of 10 mm according to the manufacturers' instructions, followed by a silane coupling agent application (Bis-silane, BISCO, Illinois, USA).

Surface roughness

The surface roughness of 10 samples from two surface treatments was measured three times by a Surftest SJ-210 (Mitutoyo, Tokyo, Japan) profilometer with 0.8 mm cut-off with respect to Ra (arithmetic mean absolute values of profile heights) and Rq (root mean square of profile heights). Three different areas of each specimen were evaluated to determine 3 Ra and Rq values, and the final value was their arithmetic mean. These specimens were not subjected to the shear bond test.

Bracket bonding

Because of the relative flatness of the bracket base, the maxillary central incisor brackets 0.018 × 0.025 inch slot size (Ortho Organizers Inc., Carlsbad, USA) with 10.5 mm^2 mean base surface area were used. The brackets were bonded to amalgam with Transbond XT and AP in Group 1, with Panavia V5 and AP in Group 2, with Panavia V5 without primer in Group 3, and with Panavia V5 and silane coupling agent in Group 4 [Table 1]. For each specimen in Groups 1 and 2 one coat of AP was used to the surface and permitted to dry for 30 s. In Group 4, one drop of each of the two bottles (Parts A and B) was dispensed into a mixing well and stirred. One coat of Bis-silane was applied to the surface and was dried with oil-free air after 30 s. According to the manufacturer's instructions, the brackets were bonded with Transbond XT in Group 1 and Panavia V5 in three other groups and were then seated at a constant pressure. Using light curing unit (Ortholux Luminous Curing Light, 3M Unitek, USA), the resin was light-cured for 20 s from both sides.

The extra resin was removed by a small round bur carefully after complete curing.[12] The samples were then put in distilled water and kept at 37°C for 24 h. All samples were thermocycled 5000 times (Delta Tpo2, Nemo, Iran) in each distilled water bath at 5°C–55°C with a 20-s immersion time, with a travel time of 10 s between the two baths at room temperature.

Shear strength testing

The bracket debonding was done by a Universal Testing Machine (K-21046, Walter + bia, Iohningen, Switzerland). A tension cell (250 kg) was used at 1 mm/min crosshead speed. Load at failure was recorded, measured in Newtons (N), and changed into megapascals (MPa) using the following equation: SBS (MPa) = Debonding force (N)/Surface area of the bracket base (mm^2) and 1MPa = 1N/mm^2. It should be noted that the samples were encoded before the bond strength test so that the operator was blind to them.

Table 1: Mean shear bond strength (MPa), standard deviation

Study Groups	*n*	Mean±SD	Minimum	Maximum
Group 1	12	1.7262±1.16510	0.36	3.94
Group 2	12	1.5677±0.92091	0.19	3.32
Group 3	12	0.8830±0.61122	0.20	2.21
Group 4	12	2.0285±1.09312	1.08	4.66

SD: Standard deviation

Failure analysis

After debonding, amalgam surfaces of all samples were analyzed by a stereomicroscope (SM P200, HP, USA) at ×10 magnification. They were then classified based on the ARI.[13] ARI scores ranged from 0 to 3 (0 = no adhesive left on the surface, 1 = less than half of the adhesive left on the surface, 2 = more than half of the adhesive left on the surface, and 3 = all adhesive left on the surface, with a distinct impression of the bracket mesh). A random sample from each group was sputter-coated with a 15-nm layer of Pt/Pd and tested under a SEM (INCAx-sight, England) at ×500 magnification and 15KV operating voltage to determine the failed surface morphology.

Statistical analysis

One-way analysis of variance (ANOVA) was run to compare groups regarding the mean SBS values in addition to the mean and standard deviation (SD). The *post hoc* Tukey test was applied for pair comparison of the groups and Kruskal–Wallis and Mann–Whitney U tests were utilized to determine surface roughness. Statistical Package for the Social Sciences (SPSS) software version 22.0 (Chicago, IL, USA) was used for all statistical analyses. It should be noted that the samples were encoded before the bond strength test so that the operator was blind to them. Statistical significance was set at $P < 0.05$.

RESULTS

Bond strength measurements

The mean SBS (mean) and SD for each of the four groups are presented in Table 1. The highest and lowest SBS mean values were recorded in Group 4 (2.02 ± 1.09 MPa) and Group 3 (0.88 ± 0.61 MPa), respectively.

The findings of one-way ANOVA indicated significant differences among the four groups in the mean SBS ($P = 0.004$). The results of *post hoc* Tukey test for pair comparison of the groups [Table 2] demonstrated a statistically significant difference between Groups 3 and 4 ($P = 0.009$). However, there were no significant differences between the other paired groups in terms of the SBS ($P > 0.05$).

Bond failure site

Table 3 shows the bonding failure modes for each of the four groups. Generally, bond failure was found to happen at the adhesive-amalgam interface. There was no failure at the adhesive-bracket interface.

Surface roughness

Mean R_a and R_q values and SD of 10 samples after two surface treatment methods are presented in Table 4. The mean R_a values in sandblast and silica coating groups were 6.88 ± 1.92 µm and 2.30 ± 0.61 µm respectively. The mean R_q values were 8.69 ± 1.85 µm in sandblast group and 3.11 ± 1.15 µm in silica coating group. The Kruskal–Wallis test indicated significant differences for mean R_a and R_q values ($P = 0.000$). Pair comparison by Mann–Whitney U test demonstrated significant differences in the surface roughness values (R_a and R_q) between Sandblast and Silica coating groups ($P = 0.009$).

The results of SEM analysis of one random sample of each group are shown in Figures 1-4.

DISCUSSION

Although the development of bonding techniques and mercury damage to human health has reduced the use of amalgam restorations, amalgam is still widely used in developing countries. Failure of bonding of orthodontic brackets to these restorations is a common clinical problem.[14]

This study compared the mean SBS of metal brackets bonded to amalgam surfaces between the groups and

Table 2: Pair comparison by *post hoc* Tukey test

Groups	Group 1	Group 2	Group 3	Group 4
Group 1	-	0.997	0.116	0.716
Group 2	-	-	0.174	0.590
Group 3	-	-	-	0.009*
Group 4	-	-	-	-

*Significant difference between two groups at $P \leq 0.05$

Table 3: Bond failure mode according to modified adhesive remnant index scoring system

Study groups	ARI score			
	0	1	2	3
Group 1	11	1	0	0
Group 2	11	1	0	0
Group 3	12	0	0	0
Group 4	11	1	0	0

ARI: Adhesive remnant index

Table 4: Mean Ra, R_q values (µm), and standard deviation

Roughness parameters	Surface treatment	*n*	Mean±SD
R_a values	Sandblast	5	6.8870±1.92759
	Silica coating	5	2.3040±0.61489
R_q values	Sandblast	5	8.6980±1.85809
	Silica coating	5	3.1148±1.15315

SD: Standard deviation

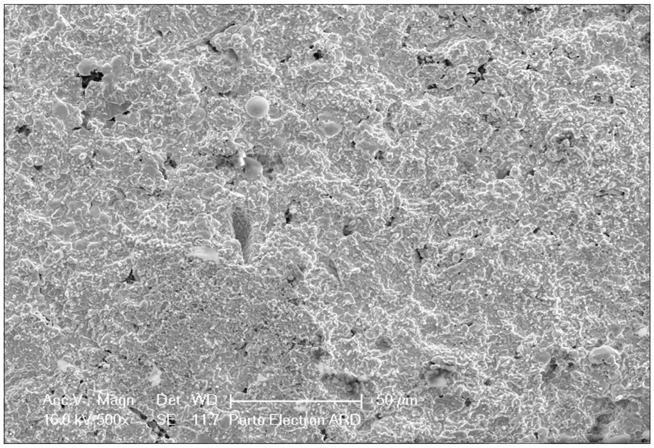

Figure 1: Scanning electron microscopic image of amalgam surface in Group 1.

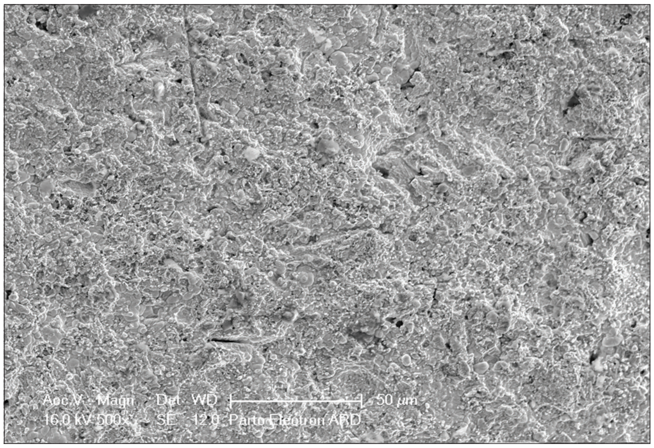

Figure 2: Scanning electron microscopic image of amalgam surface in Group 2.

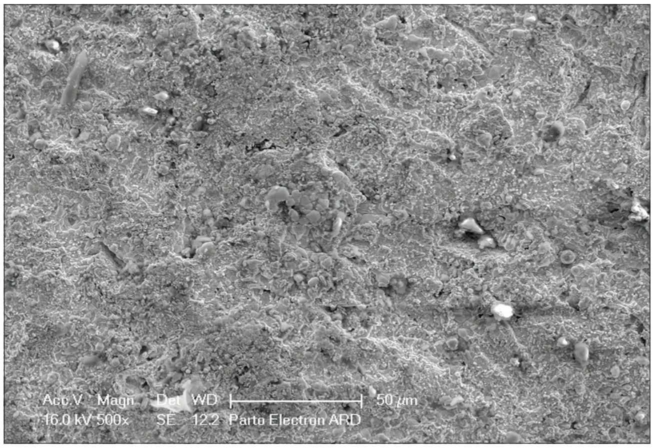

Figure 3: Scanning electron microscopic image of amalgam surface in Group 3.

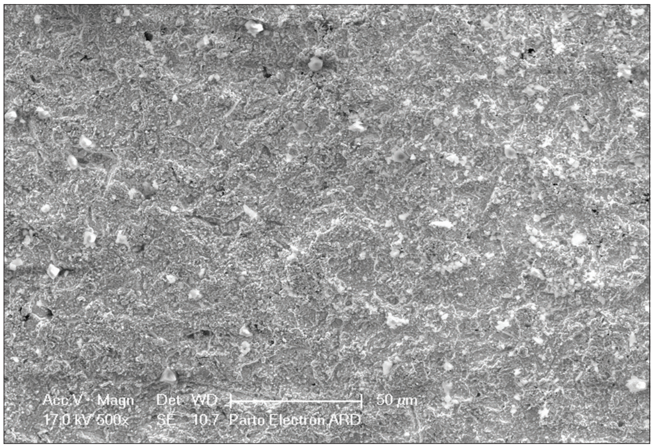

Figure 4: Scanning electron microscopic image of amalgam surface in Group 4.

also evaluated surface roughness after two surface treatments. The mean SBS values were ranged from 0.19 to 4.66 MPa. The highest mean was in the Group 4 (silica coating followed by silane) that was significantly higher than Group 3 (sandblast without Alloy primer). The results of profilometery showed that silica coating produced statistically lower surface roughness in comparison with sandblasting.

Sandblasting is a common method to prepare metal surfaces. Numerous studies have demonstrated the efficacy of this method in increasing the bond strength to the base metal surfaces, including amalgam.[3,7,15] However, Jost-Brinkmann *et al*. have proposed that the oxide layer on the surface of metals is crucial to provide sufficient bond strength between metal alloys and 10-MDP-based adhesives. Sandblasting the burnished amalgam surfaces is able to decrease the surface oxide layer and reduce the chemical bond between the 10-MDP-based adhesives and sandblasted amalgam surfaces.[16] Hence, there is a weak and perhaps negligible chemical bond between Panavia V5 resin cement and Alloy primer with sandblasted amalgam surfaces. In line with our results, Oskoee *et al*.[2] reported that the bond strength values of metal brackets with Panavia F to amalgam surfaces were not significantly different between the sandblast and control groups and were lower than those obtained in other studies such as the study of Sperber *et al*.[7]

Tribochemical silica coating has been proposed as a new air abrasion technique that is able to create ultrafine mechanical retention by sandblasting and resin-alloy chemicophysical bonding using silane coupling agent.[4] This coating method decreases the alloy composition impact and oxide layer formation on the bonding mechanism and provides a higher bond strength than either electrolytic or chemical etching.[17]

Silane-coupling agents have been used to bond organic substances to ceramic surfaces or to strengthen the metal-resin bond following tribochemical or flame-pyrolytic processes. Due to their bipolar structure, these compounds can bond silicon oxide groups on activated metal or ceramic surface to adhesives containing methyl-methacrylate or a 2,2-bis [p-(3-methacryloxy-2-hydroxypropoxy) phenyl] propane system.[18] In the current research, the SBS of brackets was significantly higher in silica coating than in sandblast without application of alloy primer ($P = 0.009$), which could be due to the chemical bond between metal and resin after silicatization. However, no statistically significant difference was found between silica coating and sandblast with Alloy primer in both Transbond XT and Panavia V5 adhesives ($P > 0.05$). Faltermeierand Behr also reported the maximum mean SBS in the silica coating group but found no significant difference between sandblast and silica coating.[18] Yetkiner and Özcan demonstrated no statistically significant differences in the bond strength of orthodontic brackets to amalgam surfaces between silanization and air abrasion with Al_2O_3 followed by monobond plus and silica coating.[19]

Restorations and adhesives in the oral cavity undergo thermal alterations that can affect the bond strength. Intra-oral temperature changes have been reported in the range of 18.9°C–48.8°C.[20] The protocol recommended by the International Standard Organization (ISO) in 2015 for thermocycling includes 500 cycles at 5°C–50°C, 20 s immersion time, and 10 s traveling time at room temperature.[21] However, the 500 cycles proposed by the ISO simulate temperature changes over a period of <2 months,[22] which is a very short time for evaluation because the time of orthodontic treatments ranges from 18 to 30 months. Therefore, in this study all samples were thermocycled for 5000 cycles between 5°C and 50°C for closer simulation of intra-oral conditions. Arici and Arici showed a decrease in the orthodontic bond strength of the no-mix adhesives as a result of thermocycling.[23] Ozcan *et al*. also reported a significant difference between resin composite and thermocycled amalgam regarding the bond strength.[10] Perhaps lower SBS values than those of other studies are due to a larger number of thermocycling in this study.

Klocke and Kahl-Nieke demostrated that the crosshead speed of 0.1–5 mm/min in the SBS test had no effect on the debonding force measurement.[24] Amalgam bonding studies have typically used a crosshead speed of 1 mm/min. We also used 1 mm/min crosshead speed to determine the SBS.

Although there is no minimum bond strength that is universally accepted to show the clinical success, Reynolds recommended the SBSs of 7.9–5.9 MPa for successful bonding in orthodontic treatments.[25] None of the obtained values in this study are enough for proper orthodontic bonding.

The ARI score of almost all samples was 0 (except 3 samples), indicating adhesion failure at the resin-amalgam interface that suggest low bond strength, which is consistent with the results of previous studies.[3,5,14] However, Gross *et al*. showed that the bond strengths to the alloy-treated amalgam were comparable with the values of etched enamel bonding, which caused amalgam fractures during debonding.[6] Thus, appropriate orthodontic bond strength to the enamel can destroy the amalgam and create fractures.

The main technique to determine surface roughness is profilometry using a fine stylus for scanning the topography in a single line of the selected area. This method has disadvantages, such as invasive nature, which can lead to surface damage during scanning, and surface defects adjacent to the scanning line, which are not measured. Therefore, these defects do not contribute to the overall measurement of surface roughness.[26] To describe surface properties, >1 surface measurement parameter has been suggested in literature because voids and irregularities can make precise measurement of surface roughness more difficult.[27] In this study, we used Ra and Rq values to describe the surface roughness, and the results showed that silica coating significantly produced less surface roughness than sandblast ($P = 0.009$). While less surface roughness was induced by silica coating, the mean SBS was higher in this group than other groups, which may be due to the chemophysical bond created by this method. In contrast to our results, Nergiz *et al*. reported similar surface roughness values for preparation with 50 µm aluminum oxide and silica coating, which were significantly less than surface preparation values with 110 µm aluminum oxide and a diamond bur.[4]

The SEM analysis showed the porous surface made after sandblasting created a dense, three-dimensional network of extensions that resembled those created after electrolytic etching of base-metal alloys.[7] Surface preparation with silica coating also produced an irregular surface with embedded silica particles.

The hardness difference between various phases in the amalgam alloy is likely to cause higher rates of erosion in the softer phases. Because various hardness of phases in amalgam alloys are common, sandblast should have a similar effect on all amalgam restorations irrespective of the shape of particle or type of alloy.[7]

CONCLUSION

With the limitation of this *in-vitro* study, it can be concluded that:

1. Mean SBS was significantly higher in orthodontic metal brackets bonded to amalgam surfaces with silica coating followed by application of silane than in sandblast without the use of the Alloy primer
2. Silica coating produced a significantly lower surface roughness than sandblast
3. Generally bond failure happed at the amalgam-adhesive interface, leaving no adhesive on the amalgam surface.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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