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# Effect of Universal Adhesive and Different Surface Pretreatments on Shear Bond Strength of Orthodontic Brackets to Amalgam Restorations: A Comparative Experimental Study

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**Objectives** Many adult patients requiring orthodontic treatment have posterior restorations. Bracket bonding to dental restorations is a clinical challenge. The aim of this study was to compare the effect of universal adhesive with the conventional method on shear bond strength (SBS) of orthodontic brackets to amalgam restorations.
**Methods** Ninety cavities were filled with admixed amalgam and divided into six groups (n=15) according to the surface pretreatment (no mechanical preparation, diamond bur preparation, and sandblasting) and type of bonding agent (alloy primer plus Transbond XT or universal adhesive). Mandibular central incisor brackets were bonded to the restoration surfaces. The primary outcome was the bond strength in megapascals (MPa) which was compared by two-way ANOVA. The mode of failure was the secondary outcome determined by determination of the adhesive remnant index (ARI). The Kruskal-Wallis and Mann-Whitney tests were used to compare the ARI scores among the groups.
**Results** Among the groups with the conventional method, the sandblasted subgroup showed the highest SBS (P<0.05). The three subgroups of universal adhesive were not significantly different in terms of SBS (P=1). Overall, the highest SBS was noted in the sandblasted/conventional adhesive group.
**Conclusion** The results demonstrated that sandblasting plus alloy primer and Transbond XT bonding agent could be recommended for bracket bonding to amalgam restorations. Further studies using other bonding agents are recommended.
**Keywords** Dental Restoration, Permanent; Orthodontic Brackets; Dental Bonding; Shear Strength

## Introduction

The increasing demand for use of bonded tubes instead of bands in posterior teeth has created challenges for orthodontists.[1, 2] In recent years, molar bonding is increasingly used due to its convenience for clinical application. Since utilization of orthodontic bands increases the risk of dental plaque accumulation, caries, gingivitis, and periodontitis, and interdental spaces remain open after band removal, the bonding method is commonly used to eliminate these shortcomings especially in patients at risk of bacteremia.[3, 4]
Dental amalgam is a suitable dental restorative material, which is widely used in restorative dentistry and has a long clinical history. It is still commonly used for posterior restorations due to its easy application, high strength and durability, bacteriostatic properties, and low cost. Evidence shows that about 100 million amalgam restorations are performed for American patients annually.[5] Approximately 50% to 85% of people have one or more amalgam restorations.[6] However, the clinical application of amalgam has dramatically decreased in developed countries due to its side effects such as mercury release.[7] However, it is still extensively used as a restorative material in developing countries such as Iran. Many adult patients requiring orthodontic treatment have small or extensive amalgam restorations in the buccal surface of their posterior teeth. However, bonding of orthodontic brackets to amalgam is a major challenge for orthodontists. One of the available solutions to this problem is replacing the restoration by using other restorative materials such as composite resin. However, toxic mercury vapor, increased urinary level of mercury, wastewater contamination, and destruction of tooth structure are inevitable during amalgam removal.[8, 9] Thus, it appears that finding methods to improve the bond strength of brackets to the existing amalgam restorations is better than banding or restoration replacement. There are several methods to enhance the bond strength of brackets to amalgam restorations, including roughening of the amalgam surface by a diamond bur or sandblasting [10], application of Gn-Sn liquid [11], chemical corrosion [12], application of metal bonding agents in association with intermediate resins, and laser irradiation of amalgam surfaces.[13] Despite the introduction of mechanical and chemical methods for amalgam surface treatment for improvement of bond strength, there is no standard guideline for this issue.[13]
Recently, a type of self-etch adhesive known as universal or multi-mode adhesive was introduced.[14] The composition of universal adhesives includes phosphate monomer (methacryloyloxydecyl dihydrogen phosphate [MDP]), silane and conventional functional monomers. The 10-MDP can chemically interact with metals, zirconia and tooth structure by creating non-soluble $Ca^{2+}$ salts. Thus, use of silane, or metal and zirconia primers is not required.[15] Universal adhesives may be able to increase the bond strength of orthodontic brackets to

amalgam restorations.

Since there are limited data on this topic, the aim of this study was to compare the effect of universal adhesive with the conventional method on shear bond strength (SBS) of orthodontic brackets bonded to amalgam restorations in vitro. Moreover, the effect of surface treatment by sandblasting or roughening by a diamond bur on SBS to amalgam was evaluated. Since a sandblaster may not be available in all orthodontic offices, we evaluated the use of diamond bur due to its easy availability.

## Methods and Materials

*Study design:*

The protocol of this study was approved by the Institutional Review Board and Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran. (IR.SBMU.RIDS.REC. 1394. 126).

In this in vitro experimental study, 90 cavities measuring 6 mm in diameter and 3 mm in depth were prepared in acrylic blocks. Cavities were filled with admixed amalgam (SDI Dental Limited, Dublin, Ireland) and the surface of restorations was burnished. According to the type of surface treatment and bonding agent used, the samples were randomly divided into six groups (A-F).

Group A: Application of Scotchbond™ universal adhesive (3MESPE, Standort Seefeld, Germany) with no amalgam surface treatment

Group B: Application of universal adhesive and sandblasting of amalgam surface

Group C: Application of universal adhesive and amalgam surface preparation by diamond bur

Group D: Application of Transbond XT (3M Unitek, CA, USA) as conventional adhesive with no amalgam surface treatment

Group E: Application of Transbond XT and sandblasting of amalgam surface

Group F: Application of Transbond XT and amalgam surface preparation by diamond bur. Each group included 15 samples.

The surface of restorations in groups B and E was subjected to aluminum oxide sandblasting with 50-µm abrasive particles (Korox 50®; Bego, Bremen, Germany) in a micro-etcher (Danville Engineering, San Ramon, CA, USA) with approximately 7 kg/cm$^2$ air pressure for 3 seconds from a distance of 10 mm and thoroughly rinsed and dried. The surface of amalgam restorations in groups C and F was roughened with a long diamond fissure bur (863 grit, Drendel and Zwilling, Berlin, Germany) by three sweeping motions of bur under constant irrigation with distilled water.

In groups A-C, one layer of universal adhesive was applied on the amalgam surface for 20 seconds using a microbrush. In groups D-F, first one layer of alloy primer (Kuraray Noritake Dental Ink, Okayama, Japan) was applied on the amalgam surface using a microbrush, then, Transbond XT adhesive was applied in two layers by a microbrush. In all groups, after five seconds of air spray, the adhesive was light cured (Optilux 501, Kerr Corporation, CT, USA) with a light intensity of 650 mW/cm$^2$ for 10 seconds. Mandibular central incisor brackets (American Orthodontics, Wisconsin, USA) were bonded to the surfaces by one operator using Transbond XT composite with 5 N load and light-cured for 40 seconds. All samples were immersed in distilled water for 24 hours and were thermocycled for 1500 cycles between 5-55°C, with a dwell time of 15 seconds, and 10 seconds of transfer time at room temperature.

*Outcome assessment:*

The SBS in megapascals (MPa) was considered as the primary outcome, and the mode of failure was the secondary outcome which was determined by assessing the adhesive remnant index (ARI). The SBS was measured (Instron Z020; Zwick/Roell, Ulm, Germany) at a crosshead speed of 0.5 mm/minute and reported in megapascals using the following formula:

SBS (MPa) = Force (Newtons)/Surface area of bracket (mm$^2$). All samples were evaluated under a stereomicroscope (ZSX9; Olympus, Tokyo, Japan) and the ARI score was determined according to Artun and Bergland (16). This score ranged from 0 to 4 as follows:

Score 0: No adhesive remnant on the surface

Score 1: Less than 50% of adhesive remaining on the surface

Score 2: Over 50% of adhesive remaining on the surface

Score 3: The entire surface of the sample is covered with adhesive

Score 4: Surface fracture

*Statistical analysis:*

Statistical analysis of the data was performed using SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA). Normal distribution of data was assessed by the Kolmogorov Smirnov test and histogram. The SBS data were reported as mean ± standard deviation and compared by two-way ANOVA. Also the Kruskal-Wallis and Mann-Whitney tests were used to compare the mode of failure and ARI scores between the groups.

## Results

Table 1 shows the mean SBS of the groups. The SBS data in the groups showed normal distribution (P>0.05).

Two-way ANOVA showed that the effect of type of adhesive and type of surface treatment on SBS was statistically significant (P=0.02). The sandblasted group bonded with conventional adhesive had significantly higher SBS compared with other groups (P<0.0001 and

P=0.007, respectively). In the conventional adhesive group, the SBS of sandblasted subgroup was significantly higher than that of bur preparation subgroup (P=0.032) and no surface treatment subgroup (P<0.000). But, no significant difference existed between bur preparation and no surface treatment subgroups (P=0.346). In the universal adhesive group, no significant difference was found among the three surface treatment subgroups (P=1.000).

**Table. 1-** Mean and standard deviation of SBS in the six subgroups

| Adhesive | Surface preparation | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Universal adhesive | No preparation | 2.30 | 1.03 | 1.38 | 3.22 |
| | Sandblasting | 2.48 | 1.39 | 1.52 | 3.44 |
| | Diamond bur | 2.29 | 0.83 | 1.40 | 3.18 |
| Transbond XT + alloy primer | No preparation | 2.76 | 1.94 | 1.88 | 3.65 |
| | Sandblasting | 5.49 | 2.31 | 4.64 | 6.35 |
| | Diamond bur | 3.81 | 1.84 | 2.85 | 4.77 |

Comparison of conventional and universal adhesive groups revealed that in general, the conventional group (alloy primer + Transbond XT) required higher force for bracket debonding than the universal adhesive group (P<0.000). Among the subgroups, surface preparation by bur (P=0.024) and sandblasting (P<0.000) subgroups of conventional adhesive group yielded higher bond strength while no significant difference was noted in bond strength of no surface treatment subgroups (P=0.472).

Table 2 shows the distribution of modes of failure in the six subgroups. As shown, score 4 was not observed in any sample, while in the conventional adhesive/bur preparation and universal adhesive/sandblasted subgroups, score 3 was the most frequent mode of failure. In the universal adhesive/no surface treatment subgroup, score 0 had the highest frequency. In the remaining three subgroups, the mode of failure was mainly score 0 and score 3. According to the Kruskal Wallis test, a marginally significant difference between universal and conventional adhesive was only noted in the sandblasted subgroups (P=0.05). In the conventional adhesive group, a significant difference was found between bur preparation and no surface treatment subgroups (P=0.039). In the universal adhesive group, a significant difference was noted between sandblasted and no surface treatment subgroups (P=0.005).

**Table 2-** Distribution of modes of failure (ARI scores) in the six subgroups

| Adhesive | Surface preparation | ARI Score 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| Universal | No preparation | 11 (73.3%) | 0 (0%) | 0 (0%) | 4 (26.7%) | 0 (0%) |
| | Sandblasting | 2 (14.3%) | 0 (0%) | 0 (0%) | 12 (85.7%) | 0 (0%) |
| | Diamond bur | 7 (50%) | 0 (0%) | 0 (0%) | 7 (50%) | 0 (0%) |
| Transbond XT | No preparation | 8 (52.3%) | 0 (0%) | 2 (13.3%) | 5 (33.3%) | 0 (0%) |
| | Sandblasting | 6 (40%) | 2 (13.3%) | 1 (6.7%) | 6 (40%) | 0 (0%) |
| | Diamond bur | 0 (0%) | 3 (20%) | 2 (13.3%) | 10 (66.7%) | 0 (0%) |

ARI: Adhesive remnant index

## Discussion

The results of the present study demonstrated that the SBS provided by the universal adhesive was lower than that by the conventional method using alloy primer and conventional bonding agent. The literature is scarce regarding the bond strength of universal adhesive to amalgam. Thus, studies on SBS of universal adhesives to other surfaces are discussed. Hattan et al.[17] measured the SBS of composite to stainless steel crowns using a type of universal adhesive and concluded that universal adhesive provided higher SBS than the conventional adhesive. In our previous studies [18, 19], we compared the bracket bond strength to composite restoration and feldspathic porcelain using universal and conventional adhesives. The results indicated that the bond strength to composite surface even without surface roughening in use of universal adhesive was similar to that in use of conventional adhesive. In addition, silane application was a more important factor than type of adhesive in bonding to porcelain surfaces. Universal adhesive with silane yielded the highest bond strength.

Sperber et al. [12] evaluated the SBS of orthodontic brackets to polished, sandblasted and chemically modified amalgam surfaces and showed that the surface topography of amalgam had a much greater effect on bond strength compared with resins. In another study by Germec et al, [20] the mean SBS to amalgam was less than that to enamel surfaces (5.99 to 7.15 MPa vs. 19.46 to 22.11 MPa). These results showed the necessity of surface preparation, which was performed in the present study. We used methods to improve the preparation of amalgam surface in order to increase the bond strength. In our study, sandblasting of amalgam increased the SBS in both groups, which was significantly greater in alloy primer plus Transbond XT group. Thus, it may be concluded that amalgam surface treatment is not required in use of universal adhesive. In the current study, surface roughening with diamond bur and sandblasting with 50-µm aluminum oxide particles were performed. Sandblasting with aluminum oxide particles results in a roughened surface similar to electrochemically etched base-metal alloys as shown by electron microscopic images.[12] This can increase the surface area and consequently the micromechanical retention and bond strength.[13, 21, 22] Also, sandblasting, irrespective of the shape and composition of amalgam particles, has the same effect on all amalgam structures. [12] Thus, we used high-copper admixed amalgam which has an appropriate structure and is commonly used in restorative dentistry. In contrast, a study by Yetkiner and Özcan[23] suggested that surface preparation by 2 methods of air abrasion and silanization was not effective for improvement of SBS to amalgam surfaces. Also, a recent study showed that silicoating by using a silane coupling agent yielded a significantly higher bond strength than sandblasting without the application of alloy primer. However, compared with sandblasting with alloy primer, silicoating did not significantly improve the bond strength.[24] Although sandblasting is known as a preferred method for preparation of amalgam surfaces, it is not available in most orthodontic offices. Moreover, application of diamond bur is more convenient due to its availability and ease of use. Thus, we aimed to also evaluate the effect of surface roughening by diamond bur for the first time in use of universal adhesive. Our results were in agreement with previous studies.[10, 12, 25] For example, Skilton et al. [10] evaluated the SBS of metal brackets to amalgam surfaces and demonstrated that SBS to sandblasted amalgam was higher than that to polished amalgam or amalgam roughened by diamond bur.

In our study, surface pretreatment was significantly effective on SBS in the conventional group using alloy primer and sandblasting. MDP, in the structure of alloy primer, chemically interacts with hydroxyapatite and phosphate moieties of nonprecious metals. Evidence shows that the hydrolytic stability of MDP bonds is more than that of other active monomers.[26] These findings describe the high SBS of alloy primer in the sandblasted groups. We believe that alloy primer is effective for improving the bond strength when used along with surface pretreatment. Wongsamut et al.[6] assessed the amalgam surface pretreatment by sandblasting and application of various primers including Monobond N (methacrylate silane), metal primer (containing 4-META), alloy primer (containing 10-MDP), Assure Plus (containing MDP), and Transbond XT (without functional monomers). A significant difference was observed between surfaces with and without sandblasting while there were no significant differences among various primers; however, the bond strength was significantly high in combined use of sandblasting and MDP-containing primer. The durability of chemical bond in use of 10-MDP was more than that in use of 4-META when exposed to oral fluids over time.

In the current study, superficial cracks or fracture in the amalgam did not occur in any group after debonding. Fracture at the bracket-adhesive interface had the highest frequency in the conventional bonding/bur preparation and universal adhesive/sandblasted subgroups. The entire adhesive remained on the amalgam surface in the afore-mentioned subgroups. However, in universal adhesive/no surface treatment subgroup, failure at the amalgam-adhesive interface had the highest frequency, and no resin remained on the amalgam surface. The mode of failure in the study by Germec et al.[20] was significantly different between the amalgam and tooth groups; and in all adhesive systems, bond failure occurred at the amalgam-adhesive interface with no damage to amalgam restoration. According to their study, failure at the amalgam-adhesive interface and residual adhesive on the amalgam surface were significantly correlated with the lowest SBS. Thus, it appears that by improving the SBS, the lowest frequency of bond failure would occur at the amalgam-adhesive interface. However, Sperber et al.[12] found that there was no association between the bond strength and mode of failure. it appears that there is a correlation between the ARI score and SBS; thus surface modifications and use of conventional adhesive with primers may increase the bond strength.

According to the recommendations of the International Standards Organization, the thermocycling instruction is as follows: 500 cycles, 5-50°C, 20 seconds of immersion time, and 5-10 seconds of transfer time at room temperature.[6] In this study, thermocycling was performed for 1500 cycles between 5-50°C, with 15 seconds of dwell time, and 10 seconds of transfer time in order to better simulate the clinical setting. The difference in SBS values reported in the present study and previous investigations may be due to different thermocycling protocols. Overall, in the current study, the amalgam surfaces bonded with conventional adhesive generally required higher force for bracket debonding than those bonded with universal adhesive. Thus, bracket bonding to amalgam surfaces using the conventional method (alloy primer + Transbond XT) appears to be more reliable. Our results showed that pretreatment of surfaces significantly increased the SBS in comparison with no surface pretreatment. Also, sandblasted amalgam subgroup bonded with conventional adhesive showed higher SBS than bur preparation. Taken together, it appears that surface pretreatment can effectively increase the bond strength in use of conventional adhesives.

This study had an *in vitro* design in which intraoral conditions and shear force cannot be well simulated. Thus, further *in vivo* studies are needed.

## Conclusion

The results of the present study demonstrated that universal adhesive yielded lower bond strength to amalgam restorations than alloy primer plus Transbond XT bonding agent. Therefore, sandblasting plus alloy primer and Transbond XT bonding agent could be recommended for bracket bonding to amalgam restorations.

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## Conflict of Interest

No Conflict of Interest Declared ■

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