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Original Article

Shear Bond Strength of Orthodontic Attachments to Amalgam Surfaces Using Assure Universal Bonding Resin after Different Surface Treatments

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Abstract

Background: Assure Universal Bonding Resin is capable of providing a strong bond between orthodontic attachments and amalgam surfaces.

Objectives: This study sought to assess the shear bond strength of orthodontic attachments to amalgam surfaces using Assure Universal Bonding Resin after different surface treatments.

Methods: This in-vitro experimental study was conducted on 120 amalgam samples in eight groups of surface roughening with diamond bur, sandblasting with aluminum oxide particles, Er, Cr: YSGG laser irradiation and polishing-only. Molar buccal tubes were bonded to amalgam surfaces using Assure primer and Transbond Plus light-cure composite. Half the samples were immediately subjected to shear bond strength testing while the remaining half were incubated at 37°C for one week, thermocycled (1000 cycles) and were then subjected to shear bond strength test. One-way ANOVA was applied to compare the bond strength of the groups and Tukey's test was used for pairwise comparisons. The adhesive remnant index (ARI; 4 point-scale) was also determined in the groups and the results were analyzed using the Kruskal-Wallis test.

Results: Significant differences were noted in shear bond strength of attachments following the application of Assure among different surface treatment modalities ($P < 0.001$); the highest bond strength was noted in sandblasted group followed by laser, bur and polishing, respectively. Aging had no significant effect on bond strength.

Conclusions: Sandblasting and irradiation of Er, Cr: YSGG laser provided sufficiently high bond strength between amalgam and attachments following the application of Assure. Diamond bur and polishing did not provide adequately high bond strength.

Keywords: Assure Universal Bonding Resin, Shear Bond Strength, Er, Cr: YSGG Laser, Sandblasting, Amalgam

1. Background

Bonding of orthodontic attachments to tooth surfaces via banding or bonding is a requirement in orthodontic treatment. Although molar bands can well resist debonding forces, bonding of molar teeth is preferred by the orthodontists and patients due to more favorable esthetics and hygiene control and less damage to periodontal tissues (1, 2). Several techniques and materials have been proposed to achieve an optimal bond to metals such as roughening the surface by diamond bur (3, 4), use of Gallium-Tin system (5) and chemical corrosion to increase the bond strength to non-enamel and amalgam surfaces. In previous studies, bond strength to amalgam restorations was reported to be significantly lower than that to enamel (5-8).

Sandblasting is another commonly used method of surface treatment for orthodontic bonding purposes (8). It has been demonstrated that alumina particles used for sandblasting create grooves on the surface and increase the surface area and subsequently the bond strength (9, 10). Some previous studies have confirmed the efficacy of sandblasting for achieving adequately high bond strength to metal alloys such as amalgam (5, 8, 11, 12).

Er, Cr: YSGG laser has also been recently suggested for surface treatment and it has been shown that this laser creates a rough surface similar to that created by conventional acid etching of the enamel and dentin (13, 14). However, risk of dislodgement of dental restorative materials such as amalgam by the use of Er: YAG laser has been reported (15).

In addition to mechanical retention, some intermediate resins have also been introduced to provide chemical retention (4, 5, 7). Assure® Universal Bonding Resin is a relatively new product with fluoride-releasing potential. It is a reinforced resin cement with hydrophilic properties. Thus, it can be applied to dry or saliva-contaminated etched enamel. In the other study the microshear bond strength of amalgam surfaces created in self-cure acrylic cavities to be 7.2 MPa following preparation using Assure. Although this value was lower than that of metal primer, the authors reported that not requiring an additional primer is an advantage in this method and called for clinical studies on bond strength of Assure to amalgam. Sperber et al. (5) evaluated the effects of different amalgam surface treatment modalities and reported high shear bond strength of resins to sandblasted amalgam surfaces.

2. Objectives

This study sought to assess the shear bond strength of metal buccal tubes to amalgam surfaces treated with four different surface preparation modalities (surface roughening by bur, sandblasting, Er, Cr: YSGG laser and polishing) using assure universal bonding resin immediately after bonding and after artificial aging.

3. Methods

In this in-vitro, experimental study, two grooves measuring 5 mm in width with smooth floors and parallel walls perpendicular to the convex surface were created in brass cylinders measuring 3.5 cm in diameter and 4.5 cm in length by a milling machine and a cylindrical milling bur.

Amalgam capsules (Admix, SDI, Melbourne, Australia) were mixed in an SDS Kerr 4000 amalgamator (KerrHawe SA) according to the manufacturer's instructions at high speed (8 seconds) and condensed in the cavities by a round faced condenser. The amalgam surface was carved and burnished in accordance with the convex surface of the brass cylinders. Samples were allowed 24 hours to set (3, 7). The samples were then polished with amalgam finishing bur (flame ELLA, Germany) and rubber cups and were randomly divided into eight groups. In two out of eight groups, amalgam surfaces were roughened by coarse 0/10 diamond bur (lasco Diamond Products, USA). In two other groups, amalgam surfaces were sandblasted by a microetcher (Pie Me S.R.L, Longigo-Veneza, Italy) using 50 μ aluminum oxide particles under 7kg/cm^2 air pressure from 10mm distance for 3 seconds. A chalky appearance after rinsing and drying of the amalgam surface was considered as a criterion for efficient sandblasting (5, 8).

In two other groups, Er, Cr: YSGG laser (Biolase Europe GmbH, Paintweg 10,92685 Floss, Germany) was irradiated with a G-type 600 μ tip at 2.78 μm wavelength, 140 - 200 μs pulse duration and repetition rate of 20Hz with an output power of 0 - 6W and 1 W power with 20% air level and 10% water level. Laser beam was irradiated perpendicular to the surface from 1mm distance for 5 seconds with the beam spot size of 0.282 mm^2 and laser energy density of 17.7 J/cm^2. After irradiation, samples were rinsed with distilled water and air-dried. In the remaining two groups, the amalgam surface was only polished and no surface treatment was done.

Molar low profile stainless steel buccal tubes (3M Unitek, Monrovia, USA) with a base measuring 6mm in length and 3mm in width were bonded to the center of amalgam surfaces parallel to the prepared surface using Assure primer and Transbond Plus light-cure composite (3M Unitek, USA). Bonding agent was applied to the amalgam surface using a microbrush, thinned with gentle air spray (without oil or water) and allowed 10 seconds to dry (3). Light-cure composite was applied to the buccal tube base and the buccal tube was placed on the amalgam surface. Pressure was applied by the tip of a scaler to the center of the tube in order for the excess resin to uniformly leak out and a thin layer of resin remained beneath the tube base. Excess resin was removed by the tip of an explorer and after ensuring the desired position, composite was light cured using a light curing unit (Light emitting diode, Mectron SPA; Carasco, Italy) with an intensity of 1400 mW/cm^2. Light curing was performed from buccal, gingival, mesial and distal directions each for 20 seconds.

Samples in four out of eight groups (one group of each surface treatment modality) were incubated at 37°C and 95% humidity for one week (Dorsa, Iran) and were then subjected to 1000 thermal cycles (Thermocycler, Dorsa, Iran) between 5 - 55°C with a dwell time of 20 seconds and transfer time of 5 seconds (5). The remaining groups were immediately subjected to shear bond strength testing after surface treatment.

Shear bond strength was measured using a universal testing machine (Zwick GmbH & Co, Ulm, Germany). Samples were placed on the jig and shear loads were applied by a blade at a crosshead speed of 1mm/min to the wider part of the base of buccal tubes at the bonding interface in occlusogingival direction until bond failure (8). Buccal tube bases had a surface area of 18 mm^2. By measuring the load at fracture in N and dividing it by the surface area, bond strength in MPa was calculated.

After debonding, buccal tubes were evaluated under a stereomicroscope (Carl/Zeiss Germany) at $\times$ 10 magnification to determine the amount of adhesive remaining on the surface using the ARI four-point scale (0 - 3) as follows (8):

Score 0: No adhesive on the amalgam surface

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

Score 2: More than 50% of adhesive remaining on the amalgam surface.

Score 3: All the adhesive remaining on the amalgam surface.

One-way ANOVA was applied to compare the shear bond strength among the groups. Tukey's test was used for pairwise comparisons. The percentage and frequency of different ARI scores in the groups based on conduction or no conduction of aging were also calculated and analyzed using non-parametric Kruskal-Wallis test (since the data did not have a normal distribution).

4. Results

The mean and standard deviation (SD) of shear bond strength of buccal tubes to amalgam surfaces following different surface treatments using Assure are shown in Table 1.

Table 1. The mean And Standard Deviation of Shear Bond Strength of Buccal Tubes to Amalgam Surfaces Following Different Surface Treatments and Application of Assure

Group	Without Aging	With Aging
Polishing	4.33 ± 0.52	3.97 ± 0.44
Bur	5.07 ± 0.67	4.81 ± 0.73
Sandblasting	7.8 ± 0.8	7.35 ± 0.97
Laser	7.01 ± 0.1	6.78 ± 0.84

The highest and the lowest shear bond strength values were found in the sandblasted, no aging group and the polished plus aging group, respectively. One-way ANOVA revealed significant differences in bond strength of buccal tubes to amalgam surfaces following different surface treatments using Assure ($P = 0.001$). The highest bond strength was noted in sandblasted group followed by laser, bur and polished groups, respectively.

The results of Tukey's test for pairwise comparison of bond strength between the groups and the respective P values are shown in Table 2.

The ARI scores following debonding in different groups are presented in Table 3. Non-parametric Kruskal-Wallis test showed no significant difference in ARI scores among different groups ($P = 0.49$).

5. Discussion

Assure® Universal Bonding Resin is the first orthodontic adhesive capable of forming a chemical bond to stainless steel. Due to chemical adhesion and adequate viscosity for flow, Assure is well capable of bonding to metal bracket bases. A suitable bracket bonding system for use in the clinical setting must be able to resist forces applied by orthodontic wires and loads applied by the oral environment. Bond strength refers to load applied to surface area unit causing bond failure, in such a way that this failure occurs at the bonding interface or close to it (16). Shear bond strength of orthodontic buccal tubes to amalgam surfaces using Assure varied from 3.97 to 7.8 MPa in our study. The bond strength in polished (no preparation) surfaces and following the use of bur was significantly lower than that in sandblasted and Er, Cr: YSGG laser groups.

Considering 5 - 8 MPa as clinically acceptable bond strength values (3), bond strength to amalgam in most surface treatment methods in our study was acceptable, and only the bond to untreated amalgam surface (polished-only) with/without aging was not adequately high. Bur preparation of amalgam surface with/without aging yielded borderline acceptable bond strength. Thus, orthodontic attachments should not be bonded to untreated amalgam surfaces in the oral environment. Bur preparation of amalgam surfaces may yield adequate bond strength immediately after preparation but it degrades over time due to aging and results in debonding and related problems in the course of treatment.

In the current study, the highest bond strength was obtained in the sandblasted surfaces (with aluminum oxide particles) bonded with Assure; laser irradiated surfaces ranked second in terms of bond strength.

Skilton et al. (11), in 2006 reported that sandblasted amalgam surfaces yielded higher shear bond strength values than polished amalgam surfaces or those roughened with diamond bur, which confirm the current results. Germec et al. (8), in 2009 reported that the shear bond strength of brackets to sandblasted amalgam surfaces was in the range of 5.99 to 7.15 MPa, which is similar to the range reported in our study; although different bonding agents were used in the two studies.

It seems that surface topography following sandblasting provides micromechanical retention for resin; moreover, chemical bonds also enhance the bond to metal (8). In the late 1970, 4-methacryloxyle ethyl trimellitate anhydride (4-META) was introduced for bonding to base metals and tooth structure (17). The 4-META molecule serves as a coupling agent and bonds to composite resin, enamel, ceramic and metals due to its potential to chemically bond to oxide layers on the surface of non-precious metals. Thus, this compound is added to some intermediate resins to enhance the bond strength (3, 17, 18). According to Jost-Brinkmann et al. (12), in 1996, the oxide layer present on the surface of metals may mediate the bond between intermediate resins containing 10-, methacryloyloxy-decyl-dihydrogen phosphate and/or 4-META to base metal alloys such as amalgam. However, since the oxide layer is thicker

Table 2. Pairwise Comparisons of Bond Strength by Tukey's Test

Group	Polished Without Aging	Polished With Aging	Bur Without Aging	Bur With Aging	Sandblasting Without Aging	Sandblasting With Aging	Laser Without Aging	Laser With Aging
Polished without aging	-	0.89	0.16	0.7	0.001	0.001	0.001	0.001
Polished with aging	0.89	-	0.004	0.069	0.001	0.001	0.001	0.001
Bur without aging	0.16	0.004	-	0.98	0.001	0.001	0.001	0.001
Bur with aging	0.7	0.069	0.98	-	0.001	0.001	0.001	0.001
Sandblasting without aging	0.001	0.001	0.001	0.001	-	0.73	0.102	0.01
Sandblasting with aging	0.001	0.001	0.001	0.001	0.73	-	0.93	0.49
Laser without aging	0.001	0.001	0.001	0.001	0.102	0.93	-	0.99
Laser with aging	0.001	0.001	0.001	0.001	0.01	0.49	0.99	-

Table 3. The Frequency and Percentage of ARI Scores Following Debonding in Different Groups[a]

Group	3	2	1	0
Polished without aging	0	0	0	15 (100)
Polished with aging	0	0	0	15 (100)
Bur without aging	0	0	1 (6.7)	14 (93.3)
Bur with aging	0	0	1 (6.7)	14 (93.3)
Sandblasting without aging	0	0	2 (13.3)	13 (86.7)
Sandblasting with aging	0	0	1 (6.7)	14 (93.3)
Laser without aging	0	0	0	15 (100)
Laser with aging	0	0	0	15 (100)

[a]Values are expressed as No.(%).

on old amalgam restorations in the oral cavity, sandblasting of amalgam restorations in the oral cavity may yield higher bond strength values compared to the in-vitro setting (8). Alizadeh Oskoee et al. (19), in 2012 reported lower bond strength values of stainless steel brackets to sandblasted (mean value of 3.56 MPa) and Er, Cr: YSGG laser irradiated (mean of 6.30 MPa) amalgam surfaces. Their results were in contrast to the current findings. Such a controversy in the results of the two studies may be attributed to different materials used (Panavia F2.0 and Alloy Primer), type of attachment (premolar bracket), prepared amalgam surfaces (straight) and type of testing machine. These factors can affect the results.

It has been demonstrated that Er: YAG laser irradiation of amalgam surfaces creates deep craters and recesses with 100 mμ diameter, and the mechanism of action of both Er: YAG and Er, Cr: YSGG lasers is similar in this respect. Preservation of the oxide layer and grooves and porosities on the amalgam surface created by Er, Cr: YSGG laser irradiation are mainly responsible for high bond strength of orthodontic attachments to laser irradiated amalgam surfaces (20). However, it should be noted that although laser irradiation of amalgam surfaces may yield adequately high bond strength values, due to the presence of mercury in dental amalgams, mercury vapor may be generated during laser ablation, which is hazardous for the health of dental staff, dentist and patient (21). Therefore, necessary measures must be taken in this respect.

After conduction of shear bond strength test, mode of failure and ARI scores must be determined. The ARI was introduced by Artun and Bergland (22) in 1984 for the purpose of standardization of bond failure analyses in orthodontic treatment. Two diverse opinions exist in previous studies regarding the site of bond failure. Bond failure at the attachment-adhesive interface or within the adhesive is more favorable since the enamel remains intact during the debonding process. On the other hand, decreased amount of adhesive remnants on the enamel surface is favored since it facilitates the process of enamel cleaning (resin remnant removal) and decreases the risk of possible traumatization of enamel during this process (8). The current study results showed that in all amalgam surface treatment modalities, ARI score was zero; in other words, adhesive remained on the buccal tubes completely; ARI score 1 was noted in only a few cases, indicating less than 50% of adhesive remnant on the amalgam surface. No case of ARI scores 2 or 3 were noted.

The amount of adhesive remnants on the surface has been evaluated in previous studies using the ARI. This index facilitates assessment of fracture surfaces. However, comparison of the results of previous studies in this respect is not easily possible since most of them modified the ARI and reported variable results. In most previous studies, failure in all or most of the samples was reported to be at the amalgam-adhesive interface (ARI = 0), which is in line with our findings (8, 22, 23). However, Sperber et al. (5) showed that high bond strength was not necessarily correlated to cohesive failure of resin.

In the current study, brass cylinders were used to simulate the amalgam restorations in the buccal surfaces of posterior teeth. These cylinders had a diameter of 3.5cm and simulated the convexity of posterior tooth surfaces, which is a strength of this study; whereas, previous studies by Buyukilmaz and Zachrisson (7) in 1998, Germec et al. (8), in 2009 and Alizadeh Oskoee et al. (19), in 2012 used amalgam discs with a straight, smooth surface for assessment of shear bond strength to orthodontic attachments. In the current study, molar buccal tubes were used to better simulate the oral clinical setting because mostly molar teeth have large amalgam restorations. Alizadeh Oskoee et al. (19), in 2012 assessed the bond strength of premolar brackets to smooth surface of amalgam discs, which may affect the generalizability of their results to the clinical setting. Buyukilmaz and Zachrisson (7) in 1998 and Germec et al. (8), in 2009 also used mandibular central incisor brackets for bond strength testing.

In the current study, after applying light-cure composite resin to the base of buccal tube, it was seated on the amalgam surface, excess resin was removed by the sharp tip of an explorer and light curing was performed. However, in the study by Buyukilmaz and Zachrisson (7) in 1998, excess resin was removed after light curing using a round bur; due to high similarity between the composite shade and tooth color, removal of excess cement would be difficult as such (7). Sperber et al. (5), in 1999 removed excess cement in two phases of before light curing of composite and after conduction of thermocycling, and then observed the samples under a light microscope. In their study, stresses applied when removing excess resin (especially resin on the bracket base margins) could have decreased the bond strength (24). In the current study, since the resin had a pink color prior to curing, removal of excess resin was done easily and accurately and composite curing was carried out with no interference (6, 25). However, the hand pressure applied for placement of buccal tubes cannot be standardized (25), which is a limitation of the current study.

In previous studies (7, 8, 26), samples were stored in water or saline at 37°C for 24 hours to 10 weeks. In the current study, artificial aging of samples was done by incubation at 37°C for one week. This may explain the differences in the results of studies. Oral clinical environment can never be exactly simulated in-vitro. Amalgam has a modulus of thermal expansion (25×10^{6}°C) higher than that of enamel (11.4×10^{6}°C) and this discrepancy causes greater expansion and contraction in amalgam compared to enamel (8). Thus, thermal changes may affect the bond strength of amalgam and enamel (27, 28). Moreover, maximum thermal alterations in the oral environment affecting dental amalgam restorations are between 18.9°C and 48.4°C (29), which can affect the results of studies as well.

5.1. Conclusion

Sandblasting and Er, Cr: YSGG laser irradiation of amalgam surfaces provide adequately high bond strength to orthodontic attachments by the use of Assure. Polishing alone and surface roughening by bur did not provide sufficiently high bond strength. Also, a significant amount of adhesive remained on buccal tubes after debonding in all surface treatment groups.

Footnote

Authors' Contribution: Study concept and design: Roya Naseh; analysis and interpretation of data: Nima Rahnamoon; writing of the manuscript: Maryam Afshari

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