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# Adhesive strength of metal brackets on existing composite, amalgam and restoration-enamel complex following air-abrasion protocols



Enver Yetkiner<sup>a,\*</sup>, Mutlu Özcan<sup>b</sup>

<sup>a</sup> Department of Orthodontics, University of Ege, 35100 Izmir, Turkey

<sup>b</sup> Dental Materials Unit, University of Zürich, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Plattenstrasse 11, CH-8032 Zürich, Switzerland

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## ABSTRACT

Bracket adhesion on restored tooth surfaces is occasionally necessary in clinical orthodontic practice. The objective of this study was to compare the effects of two air-abrasion methods on adhesion of metal brackets to enamel, resin composite, amalgam and composite/amalgam–enamel complexes. Cavities in standard dimensions (12.56 mm<sup>2</sup>) were filled with resin composite (Anterior Shine, Cavex) and amalgam (non-gamma 2, Cavex) on bovine incisors ( $N=40$ ), which were then embedded in acrylic resin. Metal brackets were bonded on the following surfaces ( $n=10$  per group): (1) enamel, (2) enamel–composite, (3) enamel–amalgam, (4) composite, and (5) amalgam. All restorative materials were either silica (SiO<sub>2</sub>)-coated (CoJet, 30 μm) and silanized (ESPE-Sil) or air-abraded with alumina (Korox, 50 μm, Al<sub>2</sub>O<sub>3</sub>) and silanized (Monobond Plus). Enamel was etched with H<sub>3</sub>PO<sub>4</sub> for 30 s in Groups 1–3. Metal brackets were bonded onto the conditioned substrates. Specimens were stored in distilled water (24 h, 37 °C) following bonding. The brackets were then debonded using a Universal Testing Machine (1 mm/min). Shear bond strength (SBS) data were recorded and failure types were categorized. Data (MPa) were analyzed using 1-way and 2-way ANOVA, Tukey's post hoc test and 2-parameter Weibull distribution. While substrate type significantly affected the SBS ( $p < 0.001$ ), surface conditioning did not show a significant effect ( $p=0.256$ ). Interaction terms were not significant ( $p=0.159$ ). Mean SBS was significantly higher ( $p < 0.001$ ) on enamel (26.72 MPa), composite (29.97–31.37 MPa) and enamel+silica-coated composite complex (25.89 MPa) than those of other groups (10.96–20.64 MPa). The presence of amalgam resulted in the lowest SBS regardless of the conditioning method (10.96–12.41). Air-abrasion with Al<sub>2</sub>O<sub>3</sub> followed by Monobond Plus and silica-coating and silanization did not show significant difference ( $p > 0.05$ ). Weibull distribution presented lower shape for restoration-enamel complexes (2.20–6.31) compared to single component surfaces (10.14–12.15). SBS on composite was similar to that of enamel but it presented predominantly cohesive failures. Failure types were frequently cohesive in composite alone or composite–enamel complex.

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## 1. Introduction

Bracket adhesion on sound enamel depends primarily on resin tag formation within the etched surface, providing micro-mechanical retention. In clinical practice however, bonding brackets on compromised tooth surfaces might be necessary when restorations are present in the targeted bonding area [1]. Resin composite, amalgam, ceramic and gold are the commonly encountered restorative materials [2]. Especially with the increase in the number of adult patients, orthodontists are more likely to bond brackets onto composite and amalgam restorations on the buccal tooth surfaces depending on the location. A vast number of studies

have been performed investigating the adhesive performance of brackets on restorative material surfaces [3–9]. Additional surface conditioning methods increasing surface roughness and the use of intermediate adhesive resin have been reported to improve bond strength on such surfaces [3–8]. These procedures have become a part of the routine clinical practice, aiming surface area increase for better micro-mechanical retention and at the same time forming chemical bonds between the adhesive and the restorative materials [9,10].

Increasing the surface area can be achieved by either abrading the surface with burs [6,7] or air-borne particle abrasion (here onwards: air-abrasion) with Al<sub>2</sub>O<sub>3</sub> or SiO<sub>2</sub> [11]. Air-abrasion produces etched-enamel like surfaces with a significant surface area increase [8,10–12] where air-abrasion with SiO<sub>2</sub>, the so-called silica coating, presents the additional advantage of providing a chemically active surface, which is then enhanced by the

\* Corresponding author. Tel.: +90 232 311 4592; fax: +90 232 388 0325.  
E-mail address: [eyetkiner@hotmail.com](mailto:eyetkiner@hotmail.com) (E. Yetkiner).

application of silane coupling agents. Commercial dental silanes contain chemical adhesion promoters such as silane methacrylate, phosphoric acid methacrylate and sulfide methacrylate through which adhesion could be enhanced [10,11]. This improvement is due to covalent bonds formed between the adhesive resin and the coated area, which is considered as an addition to the mechanical retention increasing bond strength of resin-based materials to different substrates [8,10–13]. Recently a new silane-coupling agent, universal primer, has been introduced for conditioning all types of restoration materials which is a combination of the above mentioned adhesion promoters [14,15]. Alternative to the commonly used silane, 3-methacryloxypropyltrimethoxysilane (MPS), these new primers contain cyclic disulfide, also enhancing adhesion to precious alloys. Adhesion between ceramic and luting composites using this new primer has been investigated previously [14,15]. However, there is no data reported regarding the bracket adhesion on composite or amalgam using this silane after surface conditioning based on air-abrasion protocols.

The uniformity of the targeted bonding area in orthodontics is another factor influencing the performance of contemporary adhesive procedures since at least two interfaces are of consideration: substrate surface–adhesive resin interface and adhesive resin–bracket base interface [9]. The different physical and chemical properties of these components determine the conditions of adhesion in orthodontics [9]. When the bonding area consists of not only restorative material but also the neighboring enamel, then three substances with different physical and chemical properties are subjected to surface conditioning.

The objective of this study therefore was to evaluate the bond strength of metal brackets on amalgam or composite restorative materials and on amalgam–enamel and composite–enamel complexes following two surface conditioning procedures. The tested hypotheses were that air-abrasion with  $Al_2O_3$  followed by universal primer would provide similar bond strength compared to silica-coating and MPS silane-coupling application and that bonding brackets on restoration margins would present lower bond strength than to restoration material or enamel alone.

## 2. Experimental

### 2.1. Materials and methods

The brands, types, abbreviations, chemical compositions and manufacturers of the materials used for the experiments are listed in Table 1.

#### 2.1.1. Specimen preparation

Coronal parts of bovine mandibular incisors ( $N=40$ ) stored in 0.5% chloramine solution at 4 °C for not longer than 6 months were initially cut from their roots using a low-speed diamond bur

(Isomet, Buehler, Illinois, USA) under constant water-cooling. They were embedded with their labial surfaces exposed in auto-polymerized acrylic resin (Palapress, Vario, Hereaus Kulzer, Wehrheim, Germany) in cylindrical molds (diameter: 25 mm; UnoForm, Struers, Bellerup, Denmark). Specimens were then ground flat and polished with water-cooled carborundum disks (1200, 2400 and 4000 grit, Struers, Erkrat, Germany). Cavities of standard size ( $12.56\text{ mm}^2$ ) on mesial and distal aspects of each crown were prepared using a custom-made diamond-coated trephine (inner  $\varnothing = 2\text{ mm}$ ,  $80\text{ }\mu\text{m}$ ) (Intensiv SA, Lugano-Grancia, Switzerland) under water cooling. One of the two cavities on each specimen was etched with 37%  $H_3PO_4$  (Orbis Dental, Munster, Germany) for 30 s, rinsed with water spray for 30 s and dried with compressed oil-free air. A coat of primer was applied for 15 s and gently air-thinned for 5 s. Then, a coat of bonding agent (Quadrant Unibond Sealer, Cavex, Haarlem, The Netherlands) was applied, air-thinned and photo-polymerized for 20 s. Resin composite (Anterior Shine, Cavex Holland BV) was applied in three increments, forming a smooth surface, and photo-polymerized using an LED polymerization device for 40 s (Epilar Freelight II LED, 3M ESPE, Seefeld, Germany; Output= $1000\text{ mW/cm}^2$ ) from a distance of 2 mm. Amalgam (Lathe-cut, Non-Gamma 2, Cavex Holland BV, Haarlem, The Netherlands) was condensed in the remaining cavities of the specimens until forming a smooth surface and polished with a burnisher. All specimens were re-polished with water-cooled carborundum disks (2400 and 4000 grit, Struers) in order to standardize the bonding surface for optimum bracket base adaptation. The specimens were stored in distilled water for another 48 h at 37 °C and randomly assigned to two groups for surface conditioning.

#### 2.1.2. Surface conditioning

**2.1.2.1. Silica coating and silanization.** Amalgam and composite surfaces were silica-coated ( $30\text{ }\mu\text{m } Al_2O_3$  particles modified by silica, CoJet Sand, 3M ESPE, Seefeld, Germany) using an intraoral air-abrasion device (Microetcher, Danville Eng., San Ramon, CA, USA) with a nozzle distance of approximately 10 mm at a vertical angle for 4 s at 3 psi. Then, MPS silane (ESPE-Sil, 3M ESPE) was applied every time with a new microbrush and its reaction was allowed for 30 s.

**Air-abrasion with  $Al_2O_3$  and silanization:** Amalgam and composite surfaces were air-abraded ( $50\text{ }\mu\text{m } Al_2O_3$  particles, Korox Sand, Bego, Bremen, Germany) with the same parameters used for silica coating. Then, the silane (Monobond Plus, Ivoclar Vivadent, Schaan, Liechtenstein) was applied with a micro-brush and its reaction was allowed for 60 s.

#### 2.1.3. Bracket bonding

Following these pre-treatments, metal brackets with  $8.71\text{ mm}^2$  laser-structured bases for central lower incisors (Discovery, slot  $0.56\cdot 0.76\text{ mm}/22\cdot 30$ , Dentaaurum, Ispringen, Germany) were bonded

**Table 1**

The brands, chemical compositions and manufacturers of the materials used for the experiments.

Product	Chemical composition	Manufacturer
CoJet (Sand)	$Al_2O_3 > 97\%$ , $SiO_2 < 3\%$ , $30\text{ }\mu\text{m}$ particle size	3M ESPE, Seefeld, Germany
Korox (Sand)	$Al_2O_3$ , $50\text{ }\mu\text{m}$ particle size	Bego, Bremen, Germany
ESPE-Sil	Ethanol $> 97\%$ , 3-trimethoxysilyl-propyl-methacrylate $< 3\%$ , Methyl ethyl ketone $< 2\%$	3M ESPE, Seefeld, Germany
Monobond Plus	Ethanol 50–100%, 3-methoxysilyl-propyl-methacrylate $< 2.5\%$ , Methacrylated phosphoric acid ester $< 2.5\%$	Ivoclar-Vivadent, Schaan, Liechtenstein

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