Orthodontic bonding to Adlloy-treated type IV gold

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With the introduction of acid etching for enamel surfaces[1] and recent improvements in dental adhesive materials, the attachment of orthodontic brackets using composite resins has become routine practice. However, successful bonding becomes problematic when the bonding substrate is gold. Although bands can be used in such situations, they tend to accumulate more plaque than bonded appliances.[2,3] In a previous study, roughening the gold surface with a greenstone significantly increased the resulting bond strength, although it remained weaker than an enamel-to-resin bond.[4] Microetching, tin-plating, and resin-treatments[5,6] have been introduced to enhance gold's bonding strength. However, these techniques have proven to be somewhat difficult to use and bonding to gold still presents a challenge to most clinicians. A reliable method of direct bonding to gold, especially in periodontally susceptible dentition, would be advantageous for orthodontic treatment and retention.

Adlloy, a new product developed in Japan, increases the strength of the composite-to-gold bond.[7-9] Composed of 75% gallium and 25% tin, the liquid Adlloy reacts with the gold surface to form a gallium-tin-gold alloy that enhances the bond with dental adhesives. When Adlloy is applied to gold, the gallium diffuses into the gold[8,9] and the tin remains near the surface area. The gallium- and tin-oxide film forms a 30-60 A^0 surface layer on the gold. It is these needle-like crystals of gallium- and tin-oxide that enhance retention.[7]

This new technique for preparing metal surfaces for direct bonding of orthodontic attach-

Abstract

Adlloy surface treatment of noble alloys has been shown to increase the bond strength of composite to gold alloys. The purpose of this study was to test the bond strength of Adlloy-treated type IV gold surfaces and orthodontic brackets bonded with self-curing composite resin, and compare it with sandblasted gold and etched enamel. Data were derived from a control sample of 40 human premolars and two experimental groups of Adlloy-treated and sandblasted gold surfaces. "A"-Company premolar brackets were bonded with Concise self-curing composite resin. The specimens were submerged in water for 30 days and thermocycled 1500 times before being subjected to shear bond tests. Statistically significant differences were found in the mean values of the three groups (F=124.04; df=2,117; P<.001). Bonds on the Adlloy-treated gold were twice as strong as those found on microetched gold. Adlloy surface treatment of type IV gold will permit adequate bond strength; however, FDA approval is required for intraoral use.

Key Words
Bond strength • Adlloy • Gold

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Figure 1
Gallium-tin solution (Adlloy) and the tin rod used to rub the Adlloy on the surface of the metal.

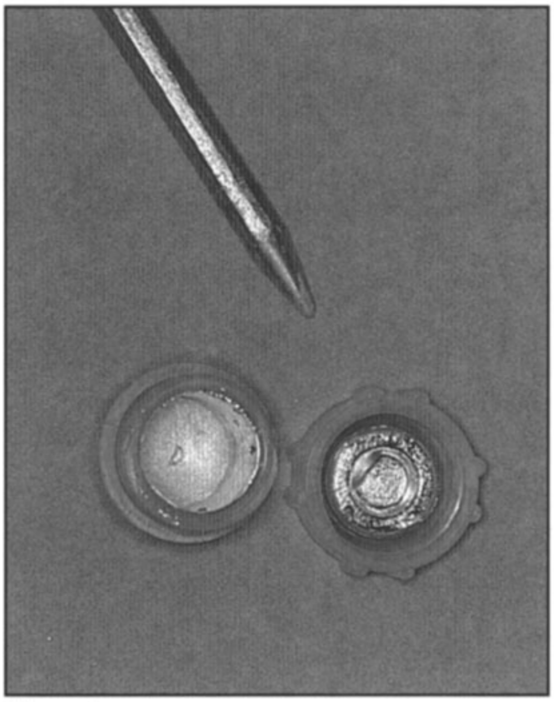

Figure 1

Table 1
30-day shear bond strength values for the three experimental samples.

	MPa
Gold+Adlloy, N=40	
Mean	6.86
SD	1.86
Gold only, N=40	
Mean	3.36
SD	1.76
Etched tooth, N=40	
Mean	11.18
SD	2.94

ments has been reported in a previous publication.[10] The authors tested bond strength of Adlloy-treated gold crowns bonded with C&B Metabond (4-META/MMA-TBB) and Concise (BIS-GMA). The specimens were submerged in water for 7 days and then tested for bond strength. The effects of thermocycling and long-term water storage on the resin-gold bond were not tested.

The purpose of this study was to test the use of Adlloy-prepared type IV gold surfaces for the bonding of orthodontic brackets using Concise dental adhesive. The study design included stressing the specimens with thermocycling and 30-day water storage.

Materials and methods

The material included a control group and two test groups. The control group comprised 40 sound human premolar teeth, extracted for orthodontic purposes and stored in tap water. The buccal surface of each tooth was polished using a 01/2 pumice and water paste. A first premolar orthodontic bracket (Micromesh, "A"-Company, San Diego, Calif,) was bonded to each tooth with Concise (3M Dental Products, St. Paul, Minn) orthodontic bonding material, following the manufacturer's directions of a 1-minute etch with 37 % orthophosphoric acid.

For the two experimental groups, type IV gold surfaces were cast in the form of buccal surfaces of a first maxillary premolar. Type IV gold consists of at least 75% gold by weight, although platinum and palladium can be substituted for gold to a certain extent. Other metals used in type IV gold include silver, copper and zinc.[11] The polished gold surfaces were sandblasted with 50m aluminum oxide abrasive using a Microetcher, model II (Danville Engineering, San Ramon, Calif) for 15 seconds at a distance of 10 mm with air pressure of 95 psi. In the first experimental group, 40 surfaces were bonded, using Concise composite resin. In the second group, 40 surfaces were treated with Adlloy and then bonded with Concise (Figure 1). Liquid Adlloy was applied to a pure tin rod and rubbed onto the sandblasted gold surface. After 60 seconds, excess Adlloy was rubbed off with gauze until the surface was clean. Orthodontic bonding followed the manufacturer's directions, with Concise applied to the bracket and then the bracket bonded to the buccal surface of the gold.

All the bonded samples were allowed to polymerize on the bench for 15 minutes before being placed in a 100% humidor for 24 hours. After 24 hours the teeth were transferred to a distilled water bath, then stored at 37°C for 30 days before thermocycling. The specimens were subjected to two thermally controlled streams of water, maintained at 10°C and 55°C, respectively. One cycle lasted 1 minute and included a 30-second dwell-time at the test range. Each specimen was thermocycled to 1500 repetitions to test the durability of bond.

The teeth were then mounted perpendicular to the base form and acrylic resin was added to approximate normal bone level. The brackets were debonded using an Instron machine to test shear bond strength. The facial surface of each tooth was aligned parallel to the plunger of the testing instrument. The crosshead speed of the Instron was set at 20 mm/min and a 50 Kg load cell was used.

Bond failure sites were evaluated for the type of failure. Adhesive failure was defined as either failure between the composite and the bracket or failure between the gold or enamel and the composite. Cohesive failure was defined as failure within the composite.

Results

The mean values of the bond strength for the three groups are listed in Table 1. The highest bond strength was recorded for the etched enamel and the lowest was for the microetched gold (Figure 2). The overall significance of these differences was evaluated in an analysis of variance (ANOVA). The results showed a significant difference between the three groups ($F=124.04$; $df=2,117$; $P<.001$). While the ANOVA showed significant results, post hoc tests were necessary to determine which group(s) differed significantly.[12] The Tukey test showed that each group differed significantly from each of the remaining two ($P<.001$ in each of the three possible comparisons). Pearson point coefficients were calculated to determine the strength of each of these three statistically significant differences involving the three groups. The coefficients were all above $r=.60$ ($P<.001$, two-tailed) and indicated high correlations. The largest difference was found when comparing the etched tooth data with microetched gold ($r=.86$). The next largest difference was found for microetched gold and Adlloy-treated gold ($r=.70$), and the smallest difference was between the etched tooth and Adlloy-treated gold ($r=.67$).

Among the etched teeth, 22% debonded with cohesive failure, 77% debonded with adhesive failure (between tooth and composite), and 1% debonded with adhesive failure (between the composite and bracket). In the microetched gold group, 100% debonded with adhesive failure between the gold and composite. In the Adlloy-treated gold group, 18% debonded with cohesive failure and 82% debonded with adhesive failure between the gold and composite. Visual inspection of the gold after 30 days of storage and thermocycling revealed a dark surface at the Adlloy-treated area (Figure 3). After rubber wheel polishing, the gold returned to a normal appearance (Figure 4).

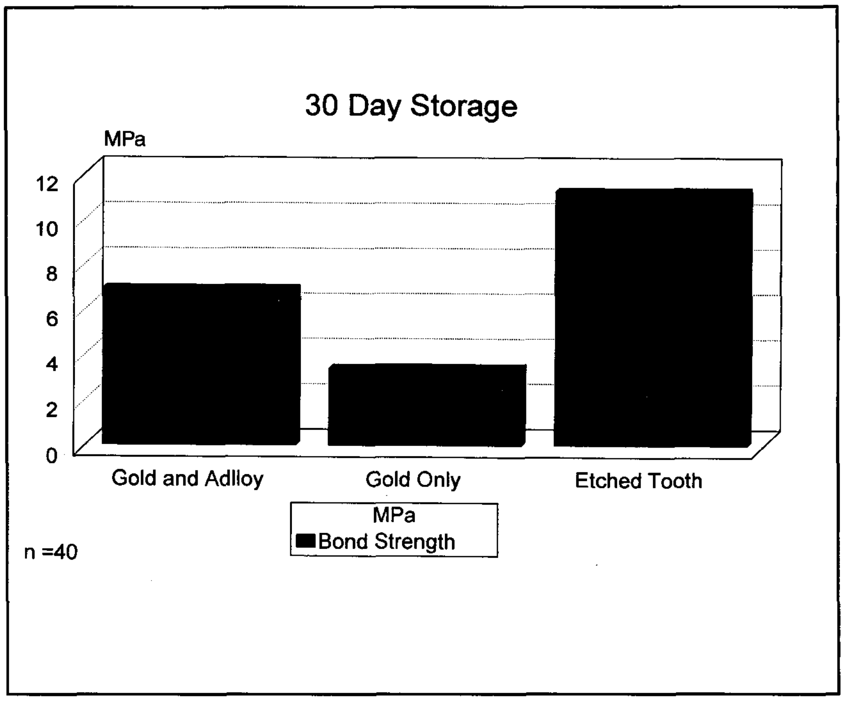

Figure 2

Figure 2
Shear bond strength.

Discussion

Bonding to gold has been studied in prosthetic dentistry for many years because of the need to bond porcelain to gold and Maryland bridges to teeth.[13-18] Only recently have orthodontists recognized the need to research bonding to metal. Alloy surface treatments, such as tin electroplating, high-temperature oxidation, immersion in oxidizing agents, ion coating ,and silicoater methods have been used in prosthetic dentistry, but transferring these techniques to orthodontic applications is difficult because in the orthodontic patient, the restorations are already in place. Fortunately, treating a gold surface with Adlloy does not require any special equipment, is time-efficient, and is easy to execute.

The bonding ability of type IV gold has been shown to increase when gold is tin-plated.[6,19,20] However, tin plating is difficult to perform intraorally. The Adlloy system allows surface modifications to be performed intraorally, although Adlloy has not yet been approved by the Food and Drug Administration for intraoral use.

In the present study, differences in bond strengths were found in the mean values for the etched teeth, microetched gold, and Adlloy-treated gold samples. The bond strength of the microetched gold was the weakest, the acid etched enamel the strongest, and the Adlloy-treated gold was of an intermediate value. The results on sandblasted gold and enamel were consistent with those reported by Zachrisson and Buyukyilmaz,[21] although their values were lower

Figure 3
Note the dark appearance of the gold after 30 days of water storage and thermocycling.

Figure 4
After polishing with a rubber wheel, the gold returned to its normal appearance.

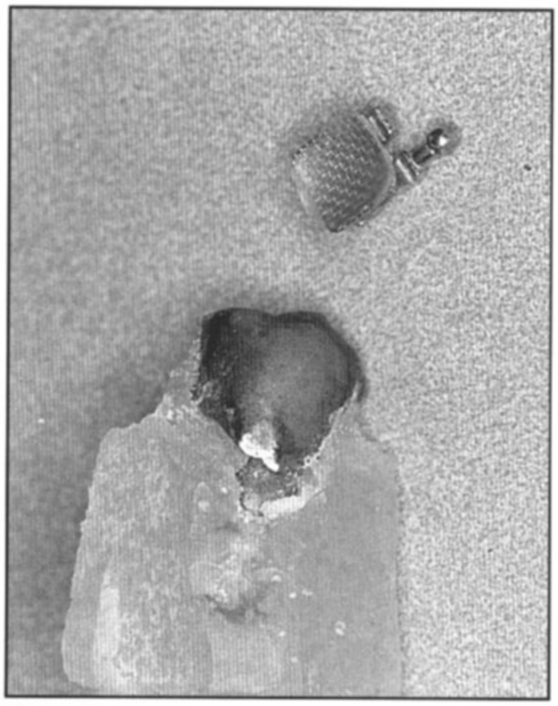

Figure 3

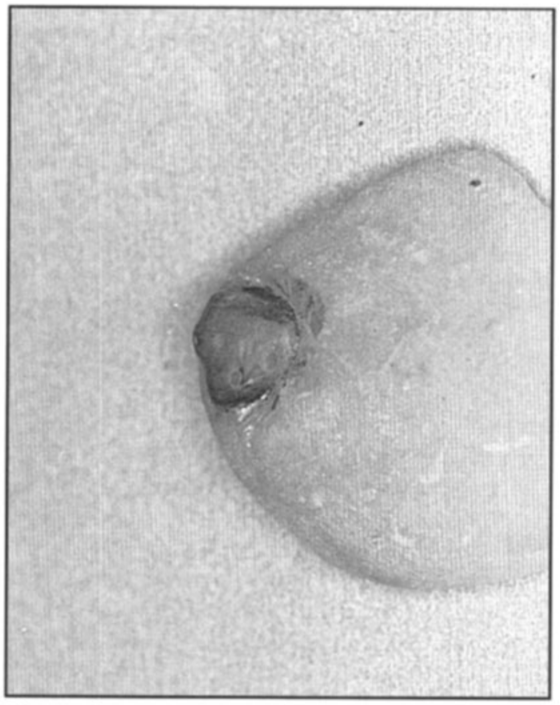

Figure 4

overall. Bond strengths reported in different studies are difficult to compare directly because of differences in testing methodology.[21] In the present study, the bond was stressed using water storage and thermocycling to create an environment close to intraoral conditions. A recent study by Buyukyilmaz, Zachrisson, and Zachrission[22] on improving bonding to gold indicated that sandblasted gold and Superbond C&B resin provided bond strength similar to conventional enamel bonding. Their overall values were higher than those found in the present study, but their sample was either thermocycled or placed in water storage, not both. Environmental stress has been shown to affect resin-to-metal bonding strength.[23] The lower bond strength values compared with other studies may be a result of thermocycling and long-term water storage. Even with these stresses, Adlloy-treated gold formed bonds that were significantly stronger than those found on amalgam bonded with All Bond 2, Geristore, or Panavia Ex.[21,23] These products have been shown to perform well intraorally when used to bond brackets to amalgam.[21,23]

Upon examination of the etched enamel bonds, fracture sites were most often found between the tooth and the composite. However, this finding is in contrast to most studies,[24-34] which have found fracture sites occur more often at the bracket-adhesive interface. In contrast, a study by O'Brien, Watts, and Read[35] suggested bond failure at either the enamel-adhesive interface or the bracket-adhesive interface could be influenced by the design of the bracket base and the adhesive material used. The increased bond stress placed on the tooth by the 30-day water storage and thermocycling in the present study may have influenced the fracture site. Failure in the sandblasted gold bonds was similar to other studies.[21,25] Bonds to the Adlloy-treated gold failed at both the adhesive-gold interface and within the adhesive. This finding was less than Buyukyilmaz, Zachrisson, and Zachrission[22] found using Superbond C&B; however, the stresses placed on those bonds were different, making comparison difficult.

Gallium-based alloys, including gallium-based amalgam, have been shown to corrode more readily than other alloys.[36] It is important to leave the gold surface in good condition after debonding. As shown in Figure 3, the Adlloy-treated gold surface had corroded after 30 days of water storage, but buffing with a simple rubber wheel brought the surface back to its original condition.

Biocompatibility is another important factor in any alloy system used in the oral cavity. Studies of allergies to gallium alloy indicate that it is not significantly different from amalgam or composite resin.[37] Gallium-based alloys have also been shown to be noncytotoxic.[38,39] Gallium-based amalgams are now being tested to replace the mercury-based amalgams as a possible means of reducing environmental risks and giving an alternative to patients with mercury allergy.

The results of this study show that Adlloy treatment can increase the bonding ability of Concise to gold. Other bonding agents, such as All Bond 2, Panavia Ex., and Superbond (4-META), have also been shown to increase bond strength to metals.[21,22] Future studies should include Adlloy treatment of gold to increase the bond strength between bonding materials such as All Bond 2, Panavia Ex. and C&B Metabond (4- META) and gold. The combined use of Adlloy and these adhesives may enable the clinician to achieve the bond strength needed to maintain brackets in areas of occlusal force.

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