Scientific Article

Composite rebonding to stainless steel metal using different bonding agents

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Abstract

The purpose of this study was to determine the in vitro bond strengths of composite rebonded to stainless steel crown metal (SS) using five different bonding agents after composite to SS bond failure had been produced. The adhesive systems were applied to the failed bonds following the manufacturers' instructions and, as a control, composite was bonded to SS without using a bonding agent. Each group was then divided into two subgroups: mechanically prepared (MP), in which the SS was roughened by a diamond bur, and unprepared (NMP), in which no modification of the SS was done. ESPE VISIO-GEM™ composite was placed in a plastic mold and light cured to the treated SS. Samples were stored in water at 37°C for 72 hr, thermocycled for 500 cycles between 5 and 55°C, and mounted in an Instron Universal Testing Machine. Caulk's Adhesive System provided significantly higher rebond strength (228.97 ± 106.9 kg/cm^2) than the other materials, and mechanical surface preparation offered no significant advantages. (Pediatr Dent 19:273–76, 1997)

Nursing caries, or baby bottle tooth decay (BBTD), is a common and serious condition affecting infants and preschool children. Because of their age and inability to cooperate, children with nursing caries frequently require a dental team, unique materials, hospitalization for BBTD restoration, and general anesthesia for treatment. It has been a challenge to find a product that is biologically, mechanically, and esthetically acceptable and offers a prolonged life expectancy in the mouth.

Preformed stainless steel crowns (SSCs) are an important restoration material for primary teeth. Although SSCs protect the teeth effectively and are functional, they are unesthetic. Several authors have suggested methods to improve the esthetics of anterior SSCs for children.[3,6,7,10] Among the most popular has been the open faced SSCs.[4,5,9] Recently, anterior SSCs with tooth-colored labial facings have been introduced. These crowns have the retentive advantage of conventional SSCs and provide excellent esthetics. Their main disadvantage is the low bond strength between the labial facing and the SSC, resulting in frequent fracture of the facing. The treatment of choice for these fractures has been replacing the crown. However, this procedure is not always possible or desirable. The additional time and expense of replacement, the possibility of the second crown also failing, and the behavior of the child all can make replacement difficult. An effective intraoral technique to repair the labial facing without changing the SSC would be of great benefit. The recent development of more effective bonding agents has made such a procedure a reasonable and appropriate goal.

This study evaluated bonding agents for intraoral repair of fractured labial facings of anterior pediatric crowns. The study consisted of an in vitro evaluation of different techniques used to rebond composite to stainless steel (SS) after debonding. The effect of mechanical preparation of the SS metal on the tensile bond strength between composite and SS also was evaluated.

Methods and materials

Three hundred sixty (360) rectangular SS metal strips (0.25 x 0.5 in.) were obtained from the 3M Company™ (St Paul, MN) for use in this study. The experiment consisted of two specific bonding and debonding components:

1a. Bonding composite resin to SS metal
1b. Debonding the composite resin and measuring the tensile bond strength
2a. Rebonding composite resin to SS metal using various bonding adhesives
2b. Debonding the composite resin and measuring the tensile bond strength.

Plastic forms were designed so that the composite materials could be bonded and rebonded to the metal under standardized conditions. The composite material was introduced in two layers. Each layer underwent separate initial curing for 20 sec using VISIO ALFA (ESPE GmbH, W. Germany) immediately after placement, and all the samples were cured for 15 min using VISIO BETA Vacuum Pump (ESPE).

Subsequently, each specimen was mounted in an Instron Universal Testing Machine (Instron Corp, Canton, MA) and subjected to tensile loading at a crosshead speed of 0.5 mm/min. The tensile bond strength was calculated as follows:

$$\text{Tensile bond strength} = \frac{\text{breaking force (kg)}}{\text{area of the bond (cm}^2\text{)}}$$

Rebonding procedure

The 360 debonded specimens were divided into six groups, each containing 60 specimens. Within each group, 30 specimens of the SS were mechanically prepared using a #4 round diamond bur (Thallidium Inc, Los Angeles, CA) by making three vertical lines crossed by three horizontal lines. The remaining 30 specimens received no preparation. Samples were coded and subsequently were drawn randomly for rebonding. Thus, the investigator was blinded to material and presence of mechanical preparation.

Materials were placed in accordance with the directions of the manufacturer. The following bonding agents were evaluated in this investigation:

- Group A: No bonding agent (control)
- Group B: Multipurpose Adhesive Bond (3M Dental Products, St Paul, MN)
- Group C: Ellman Adhesive (Ellman Int, Inc, Hewlett, NY)
- Group D: Ceramic Adhesive System (Ceramco Inc, Burlington, NJ)
- Group E: All-Bond Adhesive System (Bisco Dental Products, Itasca, IL)
- Group F: Caulk's Adhesive System (Dentsply Int Inc, Milford, DE)

In the rebonding procedure, the composite material was placed in two layers exactly as in the original bonding step. In order to more closely duplicate clinical conditions, the light source for this phase of the study was the same as that used in clinical polymerization of composite or sealant (Max Light, Caulk™, L.D. Caulk/Dentsply, Milford, DE). Curing time was adjusted (20 sec/composite layer) with a switch on the handle. The distance and direction of curing were standardized.

After rebonding, all samples were stored in water at 37°C for 72 hr and then thermocycled. The rebonded samples were debonded in the Instron machine in the same manner as for the original debonding.

Statistical analysis

This study utilized a completely random design. The data were analyzed with SPSS statistical software (Chicago, IL). A two-way analysis of variance (ANOVA) was performed to examine possible effects of bonding agents and methods of surface preparation on mean tensile bond strengths.

Comparisons among mean bond strengths of the various bonding agents and the control were tested by means of contrasts within the SPSS™ procedure ONEWAY. Because of multiple inferences, statistical significance was reserved for differences with P-values no greater than 0.0067.

Table 1. Tensile bond strength in kg/cm^2 (30/group)

Surface Treatment	*Bonding Agent*	*Mean*	*SD*	*Minimum*	*Maximum*
NMP	Control	142.09	62.81	24.74	328.17
MP	Control	183.92	64.26	94.15	332.03
NMP	Scotch-Bond	161.73	44.75	74.96	278.03
MP	Scotch-Bond	158.38	101.68	58.11	618.35
NMP	Ellman	146.04	62.42	59.19	266.93
MP	Ellman	135.47	32.82	65.99	216.71
NMP	Ceramic	167.37	71.40	69.02	317.06
MP	Ceramic	161.01	77.33	46.99	389.97
NMP	All-Bond	178.78	65.70	60.71	294.69
MP	All-Bond	186.98	74.25	71.90	378.79
NMP	Caulk	250.55	103.64	105.74	428.59
MP	Caulk	207.39	109.30	85.78	431.66

MP = Mechanically prepared samples; NMP = Nonmechanically prepared samples.

Table 2. Two-way analysis of variance

Source of Variation	*Sum of Squares*	*DF*	*Mean Squares*	*F*	*Sig of F*
Preparation	449.355	1	449.355	0.078	0.780
Material	276865.229	5	55373.046	9.632	0.000
Interaction	57192.838	5	11438.568	1.990	0.08
Residual	2000610.472	348	5648.881		
Total	2335117.894	359	6504.507		

Results

The means, standard deviations, and maximum and minimum bond strengths of the experimental and control groups are shown in Table 1. As is typical of studies of this type, a wide range of bond strengths was found.

Mechanical preparation of the base metal tended to increase the bond strength of the experimental over the control samples somewhat, but it did not affect the bond strength in any of the categories in which a bonding agent was used. Two-way ANOVA(Table 2) demonstrated statistically significant differences among the overall mean bond strengths for the five bonding agents and the control ($P < 0.001$), but there was no significant difference associated with method of surface preparation ($P = 0.780$). No significant interaction was demonstrated between the effects of bonding agents and surface preparation ($P = 0.080$).

Table 3 presents overall mean bond strengths of bonding agents, control, and initial preparation (i.e., initial bonding and rebonding strengths). Table 4 presents comparisons among the mean bond strength values for the various bonding agents and the control. The Caulk material produced significantly greater mean bond strengths than those for any of the other products (Control™, Scotchbond™, Ellman™, Ceramco™ and AllBond™ [$P = 0.006$]). In addition, the mean for the All-Bond™ group was significantly greater than that for the Ellman™ group ($P < 0.001$). No significant differences in bond strength were demonstrated among the remaining bonding agents.

The mean tensile bond strengths of all six rebonding groups were compared with initial overall mean tensile bond strength (Table 5). The initial mean value was significantly lower than those for the six rebond groups ($P < 0.001$).

Table 3. Comparison between groups mean and pooled standard deviation

Bonding Agents	*Mean*	*SD*
Control	163.003	63.54
Scotchbond	160.054	78.56
Ellman	140.753	49.86
Ceramic	164.191	74.42
All-Bond	182.882	70.11
Caulk	228.967	106.51
Initial	100.90	45.57

Table 4. Comparisons among mean bond strengths for various bonding agents and control

Comparison	*Mean Difference*	*SE of Mean Difference*	*t-value*	*P-value*
A vs B	2.95	13.04	0.226	0.822
A vs C	22.25	10.43	2.134	0.035
A vs D	-1.19	12.63	-0.094	0.925
A vs E	-19.88	12.22	-1.627	0.106
A vs F	-65.96	16.01	-4.120	0.000
B vs C	19.30	12.01	1.607	0.113
B vs D	-4.14	13.97	-0.296	0.768
B vs E	-22.83	13.59	-1.679	0.097
B vs F	-68.91	17.09	-4.033	0.000
C vs D	-23.44	11.57	-2.027	0.045
C vs E	-42.13	11.11	-3.793	0.000
C vs F	-88.21	15.18	-5.810	0.000
D vs E	-18.69	13.19	-1.416	0.159
D vs F	-64.78	16.77	-3.862	0.000
E vs F	-46.09	16.46	-2.800	0.006

A = Control Group D = Ceramic Group
B = Scotchbond Group E = All-Bond Group
C = Ellman Group F = Caulk Group

Table 5. Comparisons between group means and initial preparation mean

Comparison	*Mean Difference*	*SE of Mean Difference*	*t-value*	*P-value*
A vs Initial	62.11	8.55	7.266	0.000
B vs Initial	59.17	10.42	5.676	0.000
C vs Initial	39.86	6.87	5.801	0.000
D vs Initial	63.29	9.90	6.391	0.000
E vs Initial	81.98	9.36	8.755	0.000
F vs Initial	128.07	13.96	9.175	0.000

A = Control Group D = Ceramic Group
B = Scotchbond Group E = All-Bond Group
C = Ellman Group F = Caulk Group

Discussion

A reliable, clinically suitable and fast repair system for SSCs offers many benefits to the patient and the dentist. In vitro data[8] vary considerably and are difficult to extrapolate to in vivo conditions, but the results of this study indicate that bonding agents can increase the bond strength between the composite and debonded SS, and that bond strengths vary among bonding agents.

In the present study, ESPE Visio-Gem™ (ESPE Premier Sales Corp., Norristown, PA) was selected as the primary composite material as it is used more frequently in the manufacture of SSCs with labial facings. Also, this composite has superior viscosity, which helps in the flow of the material in the plastic forms. The use of 20-sec curing time was intended to replicate the actual clinical situation.

Of the five bonding agents used, the Caulk adhesive system produced the strongest bond. As shown in Table 5, the results of the bond strength of the initial bonding of the composite to the SS metal showed less tensile bond strength than the rebonding procedure. This might be attributed to the fact that after debonding the samples, some remnants of the composite or the adhesive agents may remain on the working area, which, in turn, create a more suitable surface for the adhesive to bond to, especially after etching. This is an important factor because in clinical situations, some composite may be left on the crown, and use of a suitable etching agent could create a more favorable surface to increase the bond during the repair procedure.

Various manufacturers produce bonding agents that use primers with different chemical compositions. On metal surfaces, primers have questionable effects.[1] Although the application of silane coupling agent (Scotchprime™, 3M, St Paul, MN) enhances the bond strength between composite and porcelain, different studies report that the bond strengths achieved with the use of primers are not high.[2, 11]

Bonding agents, on the other hand, produce a substantial improvement in the resin-to-metal bond. Aboush et al.[1] showed that Scotchbond bonding agents produced better bonding than electrolytic etching. This study also showed that bonding agents improve the bond strength between composite and stainless steel metal regardless of the mechanical preparation.

An unexpected finding was the equivalence between mechanically prepared and nonprepared groups. It generally has been assumed that mechanical preparation of the metal will enhance the retention of the composite material. In this study, careful attention was paid to standardizing the mechanical preparation. Thus it is unlikely that differences in retention could be attributed to the preparations. Although mechanical preparation might enhance initial bonding, other factors may be involved in rebonding. In this study, the mechanical preparation of the samples was accomplished using a high-speed handpiece with water spray. By the action of the diamond bur and the water, some, if not all, composite and primer remnants from the initial bonding could have been removed. This could cause the unprepared group to have superior advantages by having the composite and primer remnants attached to the metal, which might increase the bond strength. Thus, the mechanical preparation would lose its advantage.

Stainless steel strips were used in this study instead of crowns because the strips have a flat surface that can be mounted in the Instron machine. The investigators recognize that this in vitro approach does not duplicate actual jaw movement and masticatory forces in either magnitude or direction. Thus, the in vivo response to rebonding may differ from the results of this study. Nonetheless, clinical implications of this study are significant. Certain patients, due to uncompliant behavior or economic factors, make the complete replacement of an anterior pediatric crown difficult or undesirable. This study indicates that in certain clinical situations, the operator might choose to bond composite to a fractured labial facing rather than replacing the SSC. The presence of remnants of composite on the damaged surface may serve to increase the bond strength of the replacement.

In this study, five commercial bonding agents were evaluated. Several newer bonding agents recently have become available, so future research using different bonding agents can be performed. Finally, following in vitro studies, long-term clinical trials are necessary to determine the success rate of repair systems.

Summary and conclusions

In this in vitro study, composite was bonded to SS metals using different bonding agents (ScotchBond™, All-Bond™, Caulk™, Ellman™, and Ceramco™). The main conclusions of this study are:

1. Composite can be bonded effectively to SS metal using a bonding agent.
2. Bond strength of all rebonding systems was greater than the original commercially produced bond.
3. The highest bond strength following rebonding was achieved with the Caulk's Adhesive System™.
4. Ellman Adhesive System™ produced the weakest bond.
5. No significant difference was found between mechanically prepared and unprepared groups.

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