



An in vitro comparison of four surface preparation techniques for veneering a compomer to stainless steel

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Abstract

Compomers are a new class of materials reportedly having the anticariogenicity and the bonding ability to metals similar to glass ionomers while maintaining the high esthetic qualities of composite resins. The purpose of this study was to determine and evaluate the shear bond strength and fracture pattern of a compomer (Dyract™) to stainless steel crowns (SSCs) using different mechanical and chemical retention procedures for possible future development of a chair-side technique of producing esthetic SSCs. Thirty-two Unitek™ SSCs, divided into four groups, were mounted in autopolymerizing acrylic resin so that the resulting specimen has the crown's flat lingual surface projecting above and parallel to the top surface of the acrylic resin block. Dyract was placed in transparent nylon cylinders (3x3 mm) and bonded to SSC's surfaces directly (group 1) or following sandblasting of the SSCs (group 2). In group 3, Dyract was bonded to stainless steel lingual cleats that were previously spot-welded to the SSCs. In group 4, Dyract was bonded to sandblasted SSC's surfaces using Scotchbond Multi-Purpose Plus™ dental adhesive. Specimens were placed in deionized water for 1 hr at 37°C. Shear bond strength was measured using a universal testing machine. The mean (SD) shear bond strengths in MPa for groups 1-4 respectively were as follows: 2.998 (1.381), 9.518 (2.464), 13.909 (1.653), and 9.372 (3.723). One-way ANOVA and Tukey's multiple range tests revealed a statistically significant difference between the groups ($P < 0.00001$). While no significant difference was found between groups 2 and 4 in which Dyract-PSA prime/adhesive and Scotchbond Multi-Purpose Plus dental adhesive were used, group 3 had significantly higher shear bond strength than other groups. Stereoscopic and SEM examinations revealed adhesive and mixed bond failures. It is concluded that the bond strength of Dyract to SSCs could be enhanced significantly by applying simple mechanical means of retention that could be available in dental offices. (*Pediatr Dent* 19:267-72, 1997)

Since their introduction in 1947 by the Rocky Mountain Company,¹ stainless steel crowns have found a wide range of use in clinical pediatric dentistry. Although, stainless steel crowns are easy to place and can be used on teeth with little remaining

tooth structure,^{2,3} poor esthetics, particularly in the anterior teeth, are a significant concern to most parents.

The open-face SSC was an attempt to improve esthetics in which the facial surface was removed by a high-speed bur to create a window, which was filled with a tooth-colored resin.^{4,5} Open-face crowns combine durability and esthetics, but are time consuming to complete, and esthetics are still not optimal because metal may show around the resin.^{3,6} Hemorrhage can further compromise esthetics during placement of the resin window.^{3,6}

With the advent of the etched cast restorations,^{7,8} research has been devoted to resin-to-metal bonds using different techniques.⁹⁻¹¹ Bonding a white resin to stainless steel offers the potential of wider acceptance of this restoration and an entire new standard in pediatric dentistry. However, initial laboratory and clinical evaluation of bonding composite resins as veneers to SSCs did not support the use of the tested materials.¹²⁻¹⁴ Later, an esthetic technique for veneering anterior stainless steel crowns with composite resins was introduced.^{15,16}

Several dental manufacturers recently have marketed veneered SSCs for primary teeth using various laboratory bonding procedures that allow composite resins and thermoplastics to be attached or bonded to stainless steel. These ready-to-use crowns provide an esthetic restoration that can be placed in a single, short appointment, and esthetics are not affected by saliva and hemorrhage.⁶ Veneered crowns have some disadvantages including limited adaptability to the prepared teeth, liability to veneer fracture during crimping or contouring, potential heat damage to the veneer material during sterilization following unsuccessful try-ins, and high cost compared to nonveneered crowns.⁶

A new visible light-curing restorative material with properties claimed to be superior to other light-activated glass ionomers now is available and generically designated as a "compomer" marketed under the trade name "Dyract" (De Trey, Dentsply Professional Research, Kanstanz, Germany).^{17,18} Dyract is made up of strontium fluoro silicate glass contained in a newly formulated resin matrix of urethane dimethacrylate and another resin (TCB) containing two methacrylate and two carboxyl groups.¹⁷ The setting of Dyract occurs

through light activation of the resin matrix, similar to composite resins. Hydration following exposure to moisture in the oral cavity will initiate an acid base reaction between the strontium fluorosilicate glass and the carboxylic groups, which results in the release of fluoride.¹⁷ By strict definition, therefore, the compomer Dyract is not a resin-modified glass ionomer cement, but rather a composite resin with fluoride-containing fillers that upon hydration, interact with the matrix and release fluoride. The benefits of slow fluoride release in pediatric dentistry can not be overemphasized. The ability of Dyract to bond to base metal alloys has not been reported. However, this could be expected to occur through the polycarboxylic acid and phosphate groups contained in the system.¹⁷ The use of Dyract as a veneering material for SSCs is worth investigating as it could combine the anticariogenic features of glass ionomers with the esthetic qualities of composite resins. A high degree of bonding of Dyract to SSCs is a crucial factor for the success of such a technique.

The purpose of this *in vitro* study was to determine and evaluate the shear bond strength and fracture pattern of the compomer (Dyract) to stainless steel crowns using different mechanical and chemical retention procedures.

Methods and materials

Thirty-two Unitek stainless steel crowns, size LR6, (3M Dental Products Division, Ontario, Canada) divided into four groups of eight crowns were used in this study. Each crown was placed in a Polyvinyl Siloxane mold (President, Coltene/Whaledent Inc, NY) with the lingual surfaces of the crowns perpendicular to the mold walls. The mold was used to ensure that the mesiodistal and buccolingual positions of all the crowns were uniform. Each crown in the rubber mold was filled with autopolymerizing acrylic resin (Meliodent, Bayer Dental, Bayer UK Limited, UK) left to set for 1 hr, and then removed from the mold. The resulting specimens had the crowns' lingual surfaces projecting above and parallel to the top surfaces of the acrylic resin blocks. The lingual surfaces were selected as they possess a flatter surface to bond to than the labial surfaces. Dyract was bonded to the SSC's surfaces directly (group 1) and following sandblasting (group 2). In group 3, Dyract was bonded to stainless steel lingual cleats (TP Orthodontics, Inc, LaPorte, IN) with a 3-mm base diameter and 1-mm height that were previously spot-welded to the SSC's surfaces (Unitek Corporation, Monrovia, CA). The lingual cleats were chosen as means of offering mechanical retention to the resins on lingual surfaces of the SSCs. Those are available to most orthodontists and pediatric dentists, but of course their sizes could be modified by manufacturers to render them more suitable morphologically to be

TABLE 1. SURFACE TREATMENTS AND ADHESIVES EMPLOYED TO ATTACH DYRACT TO SSC'S SURFACES

Group	Surface Treatment	Material
1 (N = 8)	None	Dyract PSA Prime/Adhesive
2 (N = 8)	Sandblasting	Dyract PSA Prime/Adhesive
3 (N = 8)	Soldered cleats	Dyract PSA Prime/Adhesive
4 (N = 8)	Sandblasting	Scotchbond Multipurpose plus + Dyract

used on SSCs. In group 4, Dyract was bonded to sandblasted SSCs surfaces using Scotchbond Multi-Purpose Plus dental adhesive (3M Dental Product, St Paul, MN). The groups and surface treatments are presented in Table 1. Sandblasting (Clean Sandy, Yoshida Works, Osaka, Japan) was done by directing the aluminum oxide particles (25 μ) vertically against the crowns for approximately 25 sec under 6 kg/cm² air pressure until the metal luster disappeared completely. Dyract and PSA prime/adhesive (De Trey, Dentsply Professional Research, Kanstanz, Germany) were used according to the manufacturer's instructions (groups 1, 2 and 3). Ample amounts of PSA prime/adhesive were applied with a tiny brush to the surfaces of the crowns and left undisturbed for 30 sec, after which the excess was removed by oil-free compressed air and cured for 10 sec using a visible light curing unit (Optilux 150, Demetron Research Corp, Danbury, CT). A second layer of the PSA prime/adhesive was placed and the excess immediately removed by oil-free compressed air and then cured for 10 sec. Immediately, Dyract restorative was placed inside nylon cylinders, 3 mm high with an internal diameter (ID) of 3 mm, which were placed perpendicular to and in the center of the lingual surfaces of each crown. A 3-mm thickness of Dyract was used to facilitate handling, and testing of the specimens shearing was performed at the SSC/Dyract specimen interface, with the shear element 0.5 mm away from the interface. Dyract in the nylon cylinders was cured for 40 sec from the occlusal and gingival sides and for 20 sec from the mesial and distal sides. In group 4, the same procedures as in groups 1, 2 and 3 were carried out except that Scotchbond Multi-Purpose Plus dental adhesive instead of PSA prime/adhesive was used according to the manufacturer's instructions. The activator then primer were applied to the sandblasted surfaces of the crowns for 5 sec each, followed by the placement of the adhesive, which was cured for 10 sec prior to Dyract application. The specimens were then placed in closed containers filled with deionized water for 1 hr at 37°C (Laboratory Oven, Imperial V, Labline Instruments, Inc, Melrose Park, IL). The shear bond strength of the Dyract cylinders to the SSCs was measured using a universal testing machine (Accuforce, AMETEK, Mansfield and Green Division, Accuforce Elite Test System, Model E-500, Largo, FL; Fig 1) at a cross-head speed of 12.7 mm/min in a compression

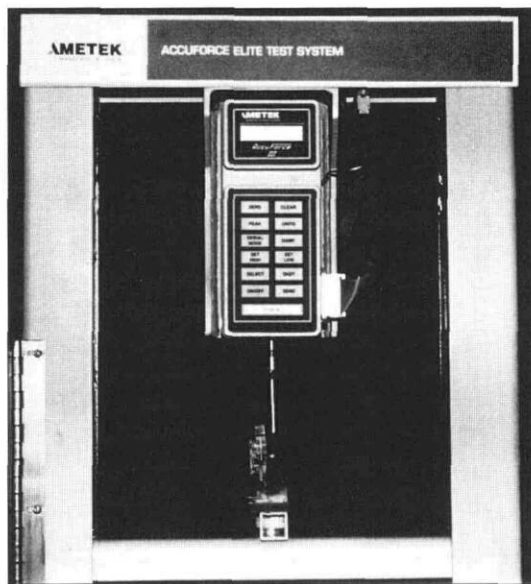


Fig 1. The mounted specimen and the Accuforce machine engaged.

mode using a blade parallel to crowns' surfaces as the shearing element (Fig 1). The bond strength at failure was calculated as the recorded failure load divided by the surface area of the inside of the nylon cylinder (7.07 mm²). The shear bond strengths were expressed in MPa. Results were analyzed using one-way analysis of variance, and Tukey's multiple range test was employed to determine the significantly different groups ($P < 0.05$).

Following shearing, the specimen-crown interfaces were examined twice by one investigator using a stereomicroscope (Wild Photomakroskop M400, Heerbrugg, Switzerland) to determine whether the bond failure was adhesive (the entire specimen being dislodged without breakage), cohesive (the adhesive being bonded to the metal but demonstrating breakage within the adhesive itself) or mixed (part, but not all of the adhesive is dislodged from the metal-specimen interface).

SSC surfaces before and after sandblasting as well as selected debonded specimens and crowns were mounted on aluminum stubs and sputter coated with gold-palladium. Specimens were examined and photographed using a scanning electron microscope

(Jeol, JSM-T330A, Jeol Ltd, Tokyo, Japan) operated at 25 KV at magnifications varying from 35x to 2000x to observe and confirm the fracture pattern.

Results

The means, SDs, coefficients of variation of the shear bond strengths in MPa, and frequency of bond failure are presented in Table 2. The lowest shear bond strength values were recorded for Dyract PSA/prime adhesive directly bonded to SSCs (group 1), while the highest values were obtained when Dyract PSA/prime adhesive was bonded to stainless steel cleats (group 3). One-way analysis of variance revealed statistically significant differences between the groups ($P < 0.00001$). The mean shear bond strengths of Dyract in group 1 (no sandblasting + Dyract PSA prime/Adhesive) to SSC surfaces was significantly lower than those of group 2 (sandblasting + Dyract PSA prime/adhesive), group 3 (stainless steel cleats + Dyract PSA prime/adhesive), and group 4 (sandblasting + Scotchbond Multipurpose Plus). There were statistically significant differences between groups 2 and 3 as well as groups 3 and 4. No significant difference was found between groups 2 and 4 in which Dyract PSA prime/adhesive and Scotchbond Multi-Purpose Plus dental adhesive were used. Group 3, in which Dyract was bonded to stainless steel cleats, was significantly higher than other groups.

For intraexaminer reliability of the failure pattern, percent agreement was 93.7%. Stereoscopic examination revealed adhesive and mixed bond failures (Table 1). For group 1, adhesive bond failure was observed in all the specimens with no breakage or chipping of the adhesive, while for group 3, all the specimens showed

TABLE 2. SHEAR BOND STRENGTH AND FREQUENCY OF BOND FAILURE TYPES FOR ALL GROUPS

Group	Surface Treatment	Material Used	Shear Bond Strength (MPa)* $\bar{x} \pm SD$	Coefficient of Variations (%)	Bond Failure: Adhesive/ Cohesive/Comb		
1 (N = 8)	No sandblasting	Dyract PSA prime/adhesive	2.99 ± 1.38†	46.06	8	0	0
2 (N = 8)	Sandblasting	Dyract PSA prime/adhesive	9.52 ± 2.46†	25.88	5	0	3
3 (N = 8)	Cleat	Dyract PSA prime/adhesive	13.91 ± 1.65†	11.88	0	0	8
4 (N = 8)	Sandblasting	Scotchbond Multipurpose Plus adhesive	9.37 ± 3.7†	39.72	6	0	2

* MPa = Mega newton / m²

† Statistically significant differences between groups 1 and 2,3,4; groups 2,3; and group 3,4 (ANOVA, $P = 0.00001$)



Fig 2. Scanning electron micrograph showing stainless steel crown surface before sandblasting (1000x).

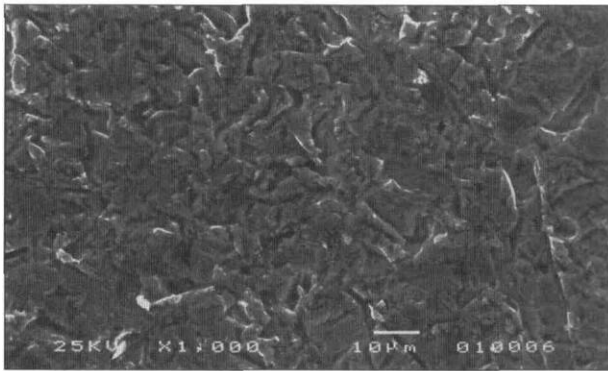


Fig 3. Scanning electron micrograph showing stainless steel crown surface following sandblasting, which created an irregular and rough surface (1000x).

mixed bond failures. For groups 2 and 4, some specimens revealed adhesive bond failure while others revealed mixed failure.

The scanning electron micrographs of the SSC surfaces before and after sandblasting (Figs 2 & 3) as well as representative debonded surfaces are shown in Figs 4 to 6. Sandblasting created irregular and rough surfaces with many undercut areas.

Discussion

Esthetics for children are important at all socioeconomic levels and it is not enough for teeth to be restored and maintained in functioning order, but with durable, retentive and esthetic restorations.

Compomers are a new class of restorative materials reportedly having the anti-cariogenicity and bonding ability to metals similar to glass ionomers while maintaining the high esthetic qualities of composite resins. If a sufficient bond strength is achieved with Dyract to SSCs, they could become a better choice as facing than composite resins due to their continuous release of fluoride, which is an asset for pediatric dental patients. Dyract has reasonably wide range of shades, which may allow better selection.¹⁷ Clinical evaluation of the compomer Dyract over a 12-month period in class V abrasion lesions showed it to be clinically acceptable.¹⁹



Fig 4. Scanning electron micrograph showing stainless steel crown surface in group 1 (adhesive failure) following debonding (2000x).

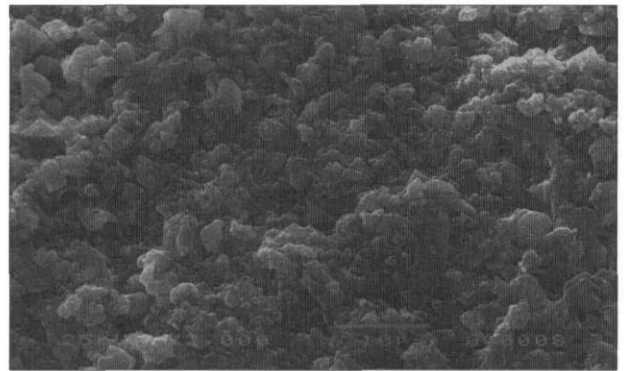


Fig 5. Scanning electron micrograph showing stainless steel crown surface in group 2 (mixed failure) following debonding (2000x).

In addition, its cyclic fatigue resistance in vitro was found to be comparable to that of composite resins.²⁰ Our in vitro study was aimed at testing the possibility of having successful bonding of a compomer to SSCs using micromechanical and chemical retention techniques, which could facilitate future development of a chair-side esthetic restoration.

In our investigation, the bond strength of Dyract bonded to stainless steel (group 1) was found to be significantly lower than other groups. A three-to four-fold increase in the mean shear bond strength was achieved in groups 2 & 4 when mechanical means of retention were introduced. The surface change to SSCs by sandblasting was evident and was confirmed by the SEM photomicrographs. Sandblasting created irregular and rough surfaces with many undercut areas in which the adhesive could wet and penetrate the SSC's surfaces creating micromechanical retention. In group 3, the use of stainless steel cleats increased the shear bond strength even more than sandblasting. The mechanical retention procedures in our study had an important role in enhancing bonding to SSCs. Previous attempts to veneer SSCs showed limited life expectancy and low shear bond strength^{13, 14} but recently a technique for veneering SSCs with composite resins that resulted in high bond strength values was described.^{15, 16}

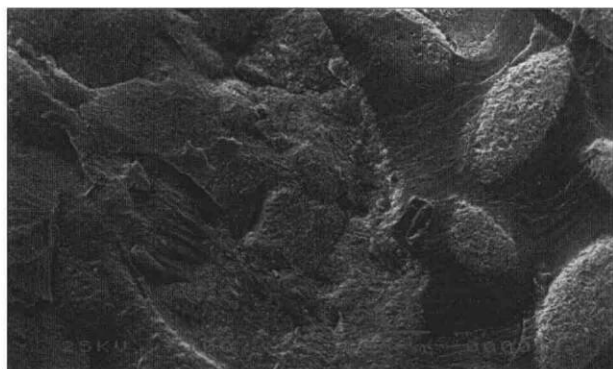


Fig 6. Scanning electron micrograph showing stainless steel lingual cleat in group 3 (mixed failure) following debonding (100x).

The strength of the adhesive bond to SSC of veneering material is important to the success of the crown. The minimum bond strength required between the veneering material and SSCs has never been defined. We could postulate that the minimum shear bond strength of the veneering material should be more or equal to the shear bond strength of composite resins to the enamel of primary teeth. In our study, the shear force required for debonding Dyract in groups 2, 3 and 4 was comparable to, or higher than the shear bond strength values reported for^{21, 22} bonding composite resins to the enamel of primary teeth.

It is believed that bonding to metals occurs between the oxygen atoms of the phosphate and polycarboxylate groups of the adhesive and the surface metal oxides.²³ Strength of the different adhesive bonds vary depending on the affinity of the individual metal oxides to the reactive groups of the adhesive.²⁴ In our study, no significant difference was found in the shear bond strength values when Dyract PSA prime/adhesive was replaced with Scotchbond Multi-Purpose Plus dental adhesive. Dyract PSA prime/adhesive contains dipentaerythritol pentacrylate phosphoric acid (PENTA) and TGDMA resin.¹⁷ Scotchbond Multi-Purpose Plus primer is composed of a mixture of hydroxyethyl methacrylate (HEMA) and a poly(alkenoic acid)-methyl methacrylate copolymer, while the Scotchbond Multi-Purpose Plus dental adhesive is a Bis-GMA/HEMA mixture.²⁵ Despite the difference in the formulations between the two materials, they both could bond to the metal oxides of stainless steel via the polycarboxylate and phosphate groups contained in them. The similar shear bond strength values might indicate that the chemical bonds achieved with those adhesives to stainless steel are of comparable strengths, or that micromechanical retention has an overriding role. The latter seems the most probable since bonding Dyract to stainless steel without sandblasting (group 1) yielded the lowest shear bond strength values obtained in this study.

An adhesive fracture is defined as one that takes place between dissimilar substances while a cohesive fracture

takes place within a substance.²⁶ In our study, failures for group 1 and some specimens for groups 2 and 4 were adhesive and the specimens separated at the SSC/adhesive interface. All the specimens in group 3 and some specimens in groups 2 and 4 showed a mixed failure pattern. The scanning electron micrographs showed that resins could be bonded to metals that have only been sandblasted. Many small adhesive tags were seen on the sandblasted surfaces. Sandblasting increases the surface area compared with the smooth surfaces of non-sandblasted crowns. It could be assumed from this result that part of the strength of the bond to stainless steel is due to adhesive tags, which mechanically interlock the material in the stainless steel surface.

The coefficient of variation of shear bond strength in our study was very high in some groups. A contributing factor to this large variation could be due to specimen preparations. Tests of adherence in ideal conditions usually have high variation since failure is often due to specimen imperfections of which the investigator is unaware. This variation might have been reduced by further standardization and applying a constant load during polymerization of Dyract. However, in the clinical situation this standardization is not always possible and therefore, a comparable variation may be feasible.

No thermocycling was done to the specimens of this study prior to shear bond strength testing. In clinical situations, thermal changes would be expected, it is conceivable that this might affect the bond stability of the facings to the SSCs. The value of the coefficient of thermal expansion of Dyract has not yet been reported, and whether it is higher than other resin facing warrants further investigation. Moreover, flatter mesh rather than lingual cleats probably will need to be used in clinical situations, and their contribution to micromechanical bonding also will need to be investigated in the future. The limited surface used to measure bond strength (7.07 mm) may reflect bond strength to a full crown's facial surface. However, the thickness of the material in limited surface versus a full crown's facial surface warrants further investigation.

The dexterity of clinicians, the time required to perform the technique, and the durability of the product are essential factors in the delivery of any dental esthetics service to patients. Mechanical and chemical bonding of restorative materials to SSCs as a chair-side technique could be an option in the hands of clinicians as it has several advantages over other anterior esthetic restorations. These include easy repairing and contouring of the restorative material, variety of shade selection, easy adaptation and contouring of the crowns before bonding to avoid veneering fracture, and heat sterilization after unsuccessful try-ins. SSC manufacturers should be encouraged to fabricate and supply such crowns with sandblasted and/or corrugated facial surfaces as this could render the procedure of making chair-side esthetic SSCs quick and simple.

Conclusions

1. The shear bond strength of Dyract to stainless steel crown was greatest for the welded cleat group.
2. No differences in bond strength were noted for the two sandblasted groups of crowns when two different bonding systems were used.
3. Dyract had the weakest bond strength when applied directly to the untreated surface of the crown.

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