Effects of surface treatment and bonding agents on bond strength of composite resin to porcelain

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This study evaluated porcelain repair by use of various surface treatments and hydrophilic bonding resins. The surface treatments were air abrasion (sandblasting), roughening with a diamond, etching with 9.6% hydrofluoric acid, and a combination of the latter two methods. A silane coupling agent was applied to all porcelain surfaces, and composite resin was bonded to porcelain with All-Bond 2, Amalgambond, or Clearfil Porcelain bonding agents. Shear bond strengths were determined on a universal testing machine. The most effective surface treatment was the combination of diamond roughening and hydrofluoric acid etching, but it was not significantly better than the other methods. The Clearfil Porcelain Bond system showed a greater repair strength than the other two materials but was statistically different only from Amalgambond resin. (J PROSTHET DENT 1993;70:118-20.)

Fractures of ceramic and ceramometal restorations are a frustrating but not uncommon problem in restorative dentistry, so various methods have been introduced to repair fractured porcelain with composite resin. Mechanical roughening of porcelain surfaces with a coarse diamond has improved repair strengths.[1, 2] Air abrasion (sandblasting) with aluminum oxide is another method of surface roughening,[3] and porcelain can also be etched with hydrofluoric (HF) acid to facilitate micromechanical retention of composite resin.[4, 5]

Silane coupling agents, which chemically bond organic and inorganic substances, were first introduced 40 years ago.[6] Silanes were introduced in dentistry by Bowen and Rodriguez,[7] who developed composite resins by adding silanated filler particles to Bis-GMA resin. Silane coupling agents can also improve the bond of composite resin to porcelain by approximately 25%.[8-11]

The bond strength of composite resin to porcelain is also affected by the bonding agent and type of composite resin used for repair.[3, 12-16] For example, hybrid composite resins generally provide higher bond strengths than microfilled composite resins.[15, 16]

This study evaluated bond strengths in composite resin and porcelain by use of four different porcelain surface treatments and three different bonding agents.

MATERIAL AND METHODS

Sixty porcelain buttons (approximately 1 cm in diameter and 0.5 cm thick) were made in a circular split brass mold. Vita VMK 68 542 body porcelain (Vident, Baldwin Park, Calif.) powder and liquid were mixed, prepared, and fired in a computerized oven (Ultra-Mat, Unitek Corp., Monrovia, Calif.) according to the manufacturer. The samples were polished with 400 grit and 600 grit wet sandpaper to create a smooth surface, and each porcelain button was embedded in a phenolic ring (Buehler, Ltd., Lake Bluff, Ill.) with dental stone. The porcelain surface was covered with transparent tape to prevent contamination during embedding.

Sixty specimens were randomly assigned to one of four groups for surface treatments:

Group 1. Porcelain was roughened with a water cooled 799.6½ diamond bur (Brasseler USA, Savannah, Ga.), rinsed with water, and dried with oil-free compressed air.

Group 2. Porcelain surfaces were etched for 2 minutes with 9.6% HF acid (Pulpdent Corp., Watertown, Mass.), rinsed for 1 minute, and dried with air.

Group 3. Porcelain was air abraded with 50 μm aluminum oxide particles for 15 seconds with an intraoral sandblasting device (Microetcher, Danville Engineering, Danville, Calif.), rinsed, and dried.

Group 4. Porcelain surfaces were roughened with a diamond bur and etched with HF acid, combining the treatments in groups 1 and 2.

A silane coupling agent (Pulpdent Corp.) was applied to the porcelain and allowed to air dry. Each of the four main groups was divided into three subgroups ($n = 5$) for treatment with different bonding systems. The adhesives were used in accordance with the manufacturer:

Amalgambond (Parkell, Farmingdale, N.Y.). Adhesive "AA" was applied with a brush, retained for 30 seconds, then blown gently with air to a thin layer. Two drops of base "B" were mixed with one drop of catalyst "C" and brushed on the surface, creating a thin film that was not allowed to dry before application of composite resin.

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0022-3913/93/$1.00 + .10. **10/1/46863**

Table I. Shear bond strengths (MPa) of composite resin to porcelain after different surface treatments and application of various bonding agents ($n = 5$)

Surface treatment	Bonding agent	Mean	SD
HF	Clearfil	19.72	7.73
Diamond + HF	Amalgambond	18.11	2.09
Diamond + HF	Clearfil	17.56	7.05
Diamond	Clearfil	16.98	6.24
Sandblasting	Clearfil	16.86	4.70
HF	Amalgambond	16.20	3.01
Diamond	All-Bond 2	16.10	2.44
Diamond + HF	All-Bond 2	15.79	3.69
HF	All-Bond 2	14.28	3.28
Sandblasting	All-Bond 2	13.74	6.22
Diamond	Amalgambond	9.79	2.32
Sandblasting	Amalgambond	9.52	1.24

HF, Hydrofluoric acid; *SD*, Standard deviation.

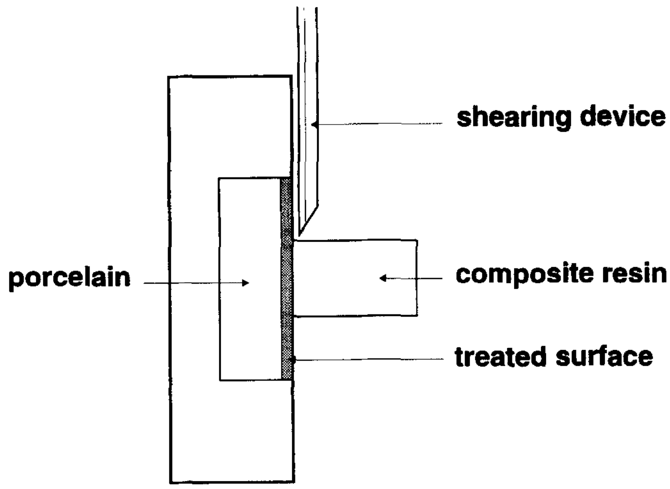

Fig. 1. Schematic drawing of repaired specimen in testing apparatus.

Table II. Shear bond strengths (MPa) of composite resin to porcelain with the use of various bonding agents ($n = 20$)

Bonding agent	Mean*	Duncan grouping†
Clearfil	17.78 (6.11)	A
All-Bond 2	14.98 (3.94)	A B
Amalgambond	13.40 (4.42)	B

*Standard deviations are listed in parentheses.
†Means with same letter are not significantly different (alpha = 0.05).

All-Bond 2 (Bisco Dental Products, Itasca, Ill.). A thin layer of Dentin/Enamel Bonding Resin material was applied to the porcelain surface with a brush and light cured for 20 seconds.

Clearfil Porcelain Bond (Kuraray, Ltd., Japan and J. Morita USA, Inc., Tustin, Calif.). The three-component adhesive was mixed for 5 seconds, brushed on the porcelain, and then dried with compressed air for 2 to 3 seconds.

After surface preparation of the porcelain and application of the bonding agents, a hybrid composite resin (Prisma AP.H, Caulk/Dentsply, Milford, Del.) was applied to the porcelain in 3.96 mm diameter gelatin capsules (Eli Lilly and Company, Indianapolis, Ind.). The composite resin was cured for 40 seconds from five different directions for a total of 200 seconds curing time with an Optilux 401 light-curing unit (Demetron Research, Danbury, Conn.). The samples were placed in abeyance for 30 minutes before storage in distilled water for 1 week. After storage, the samples were thermocycled for 500 cycles between water baths at 5° and 55° C, with a dwell time of 30 seconds in each bath. After thermocycling, the specimens were debonded in an Instron universal testing machine (Instron Corp., Canton, Mass.) with shear force until fracture (Fig. 1), with a crosshead speed of 0.5 cm/min and 500 kg load cell. Fracture loads (kg) were converted to bond strengths (MPa) by use of the cross-sectional area of the composite resin buttons.

RESULTS

Bond failures were predominantly cohesive in porcelain or composite resin. However, specimens repaired with the All-Bond 2 system on HF acid–etched or sandblasted porcelain commonly had adhesive failures at the porcelain/composite resin interface.

The mean shear bond strengths of all experimental groups are listed in Table I. Two-way analysis of variance (ANOVA) revealed that the bonding agent was the only statistically significant factor ($p < 0.02$) in bond strengths. The type of surface treatment did not have a statistically significant effect, and there was no significant interaction between surface treatment and bonding agent.

The combined data compared the specific bonding agents or surface treatment. ANOVA and Duncan's multiple-range test showed that the Clearfil bonding agent recorded a significantly greater mean bond strength than the Amalgambond system (Table II). Surfaces that were etched with HF acid, with or without prior mechanical roughening, recorded greater bond strengths than surfaces that were roughened with a diamond or sandblaster but not etched. However, the differences were not statistically significant.

DISCUSSION

The most effective surface treatment was a combination of mechanical roughening with a diamond bur and chemical etching with HF acid. This combination provided slightly greater repair strengths than either method separately. Air abrasion (sandblasting) resulted in lower bond strengths than the alternate methods. However, these differences were not statistically significant, so mechanical roughening by use of a diamond or intraoral sandblaster may be adequate for many porcelain repairs. Etching with

HF acid should also be considered in higher stress areas, or if the greatest possible bond strength is indicated.

The results of this study differ from those of Bertolotti et al.[3] who reported higher bond strengths with air abrasion than with diamond roughening. However, Bertolotti's study also showed that the Clearfil Porcelain Bond system recorded stronger bonds between composite resin and porcelain than a phosphonate ester bonding agent.

Clearfil and the other adhesives evaluated in this study are more hydrophilic than conventional unfilled resins. Each contains one or more hydrophilic resin monomers. The All-Bond 2 Dentin/Enamel Bonding Resin system contains hydroxyethyl methacrylate (HEMA) in addition to the hydrophobic resins Bis-GMA and urethane dimethacrylate.[17] The Amalgambond resins include HEMA, 4-META, and methyl methacrylate.[18] Clearfil Porcelain Bond system contains Bis-GMA, HEMA, a phosphate monomer (MDP), plus a silane.[3, 19]

Clearfil adhesive includes this silane component, so prior silanation of the porcelain surface is not required, and the manufacturer also states that HF acid etching is unnecessary. Phosphoric acid is applied to acidify porcelain before application of the silane/bonding resin. However, to standardize the experiment, porcelain was etched with HF acid and silanated in all treatment groups. The results indicated that these treatments did not adversely affect the Clearfil Porcelain Bond material. Nevertheless, the silane component in Clearfil adhesive may be partly responsible for the greater bond strengths with this product than with the other adhesives.

Kanca[17] reported a shear bond strength of composite resin to sandblasted porcelain of 27.4 MPa with the All-Bond method. He used primer B (biphenyl dimethacrylate, or BPDM) after silanating the porcelain, but the All-Bond 2 directions for porcelain repair, at the time of this study, indicated that primers A and B were only applied to exposed metal. Presumably these hydrophilic resins would also improve the repair strength if applied to porcelain.

Cooley et al.[12] tested a porcelain repair system (Etch-Free Primer with C&B Metabond, Parkell) that is similar to the Amalgambond system and reported shear bond strengths of 17.4 to 19.1 MPa to diamond-roughened porcelain. Metabond adhesive has superior physical properties, such as compressive strength, compared with Amalgambond adhesive, and combined with Cooley's use of Etch-Free Primer material, probably accounts for the differences between the two studies.

SUMMARY

Scanning electron microscopy is currently used to evaluate the effects of different surface treatments on porcelain, and will also be used in the future to examine the influence of bonding agents on porcelain repair procedures.

This study was conducted under controlled laboratory conditions, so the results may not accurately predict the clinical performance of various porcelain repair methods.

Materials for this project were provided by Bisco Dental Products, Caulk/Dentsply, Parkell, Pulpdent Corp., and J. Morita USA, Inc. We thank Jane Jakobsen for her assistance with the statistical analysis.

REFERENCES

1. Jochen DG, Caputo AA. Composite resin repair of porcelain denture teeth. J PROSTHET DENT 1977;38:673-9.
2. Ferrando JMP, Graser GN, Tallents RH, Jarvis RH. Tensile strength and microleakage of porcelain repair materials. J PROSTHET DENT 1983;50:44-50.
3. Bertolotti RL, Lacy AM, Watanabe LG. Adhesive monomers for porcelain repair. Int J Prosthodont 1989;2:483-9.
4. Simonsen RJ, Calamia JR. Tensile bond strength of etched porcelain [Abstract]. J Dent Res 1983;62:297.
5. Stangel I, Nathanson D, Hsu CS. Shear bond strength of the composite bond to etched porcelain. J Dent Res 1987;66:1460-5.
6. Bjorksten J, Yaeger LL. Vinyl silane size for glass fabric. Mod Plast 1952;29:124-8.
7. Bowen RL, Rodriguez MS. Tensile strength and modulus of elasticity of tooth structure and several restorative materials. J Am Dent Assoc 1962;64:378-87.
8. Lacy AM, LaLuz J, Watanabe LG, Dellinges M. Effect of porcelain surface treatment on the bond to composite. J PROSTHET DENT 1988;60:288-91.
9. Sheth J, Jensen M, Tolliver D. Effect of surface treatment on etched porcelain and bond strength to enamel. Dent Mater 1988;4:328-37.
10. Diaz-Arnold AM, Schneider RL, Aquilino SA. Porcelain repairs: an evaluation of the shear strength of three porcelain repair systems [Abstract]. J Dent Res 1987;66:207.
11. Newburg R, Pameijer CH. Composite resin bonded to porcelain with a silane solution. J Am Dent Assoc 1978;96:288-91.
12. Cooley RL, Tseng EY, Evans JG. Evaluation of a 4-META porcelain repair system. J Esthet Dent 1991;3:11-3.
13. Barkmeier WW, Latta MA. Shear bond strength of Dicor using resin adhesive systems and light activated cement. J Esthet Dent 1991;3:95-9.
14. Matsumura H, Kawahara M, Tanaka T, Atsuta M. A new porcelain repair system with a silane coupler, ferric chloride, and adhesive opaque resin. J Dent Res 1989;68:813-8.
15. Gregory WA, Hagen CA, Powers JM. Composite resin repair of porcelain using different bonding materials. Oper Dent 1988;13:114-8.
16. Gregory WA, Moss SM. Effects of heterogeneous layers of composite and time on composite repair of porcelain. Oper Dent 1990;15:18-22.
17. Kanca J. Dental adhesion and the All-Bond system. J Esthet Dent 1991;3:129-32.
18. Cooley RL, Tseng EY, Barkmeier WW. Dentinal bond strengths and microleakage of a 4-META adhesive to amalgam and composite resin. Quintessence Int 1991;22:979-83.
19. Albers HF, ed. Dentin-resin bonding. ADEPT Report 1990;1:33-44.

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