Short Communication

Repair Bond Strength of a Resin Composite to Alumina-Reinforced Feldspathic Ceramic

Tamiye Simone Goia, DDS[a]/Fabíola Pessôa Pereira Leite, PhD[a]/Luiz Felipe Valandro, PhD[b]/
Mutlu Özcan, DMD, PhD[c]/Marco Antonio Bottino, PhD[d]

This study compared the microtensile bond strength of a repair resin to an alumina-reinforced feldspathic ceramic (Vitadur-α, Vita) after 3 surface conditioning methods: Group 1, etching with 9.6% hydrofluoric acid for 1 minute plus rinsing and drying, followed by application of silane for 5 minutes; group 2, airborne particle abrasion with 110-mm aluminum oxide using a chairside air-abrasion device followed by silane application for 5 minutes; group 3, chairside tribochemical silica coating with 30-µm SiO_x followed by silane application for 5 minutes (N = 30). Group 1 presented the highest mean bond strength (19.7 ± 3.8 MPa), which was significantly higher than those of groups 2 (10 ± 2.6 MPa) and 3 (10.4 ± 4 MPa) ($P < .01$). Scanning electron microscope analysis of the failure modes demonstrated predominantly mixed types of failures, with adhesive and/or cohesive failures in all experimental groups. *Int J Prosthodont 2006;19:400–402.*

The principles of minimally invasive dentistry aim for preservation of tooth structures and prolongation of the service life of existing restorations. Use of adhesive techniques allows the clinician to make repairs in vivo for failed restorations. Inlay, onlay, and laminate types of adhesively luted fixed partial dentures are generally fabricated using feldspathic- or leucite-based esthetic dental ceramics. Glass-based ceramics present a fracture strength of approximately 2 $MPam^{1/2}$ and a flexural strength of 180 MPa, whereas alumina- and/or zirconia-reinforced ceramic frameworks exhibit a fracture strength of 6 $MPam^{1/2}$ and a flexural strength of about 700 MPa.[1] Therefore, glass-based ceramics are more susceptible to fracture, as reported in clinical studies.[2,3]

Depending on the reason for fracture, repair may be indicated using adhesive techniques in combination with resin composites that require etching of the ceramic surface to optimize the adhesion of the repair material.[2] Ceramic surface treatment may be performed with hydrofluoric (HF) acid etching or airborne particle abrasion followed by application of a silane coupling agent. Recently, feldspathic ceramics have been reinforced with alumina. Controversial reports exist in the literature regarding their conditioning prior to repair, using either HF acid application and silanization or employing airborne particle abrasion.[4,5] However, as this type of ceramic presents a medium content of alumina, and since alumina cannot be etched, this study compared 3 surface conditioning methods that are indicated for the repair of high-alumina ceramics. Because of the glass content of this alumina-reinforced ceramic, it was hypothesized that HF acid and silanization would provide the highest repair bond strength.

[a]Researcher, Department of Dental Materials and Prosthodontics, Federal University of Santa Maria, Brazil and São Jose dos Campos Dental School, São Paulo State University, São Jose dos Campos, Brazil.
[b]Associate Professor, Department of Restorative Dentistry, Federal University of Santa Maria, Brazil and São Jose dos Campos Dental School, São Paulo State University, São Jose dos Campos, Brazil.
[c]Adjunct Professor, Department of Dentistry and Dental Hygiene, Faculty of Medical Sciences, University of Groningen, Groningen, The Netherlands.
[d]Chairman and Professor, Department of Restorative Dentistry, Federal University of Santa Maria, Brazil and São Jose dos Campos Dental School, São Paulo State University, São Jose dos Campos, Brazil.

Correspondence to: *Dr Mutlu Özcan, Department of Dentistry and Dental Hygiene, Faculty of Medical Sciences, University of Groningen, Antonius Deusinglaan 1, 9713 AV Groningen, The Netherlands. E-mail: mutluozcan@hotmail.com*

Table 1 Characteristics of Ceramic Surface Conditioning Methods

Group (n = 10)	Conditioning method
1	Etching with 9.6% HF* for 1 min + rinsing and drying + application of silane† for 5 min
2	Airborne particle abrasion‡§ with 110-µm Al_2O_3 using a chairside air-abrasion device + silane† application for 5 min
3	Chairside tribochemical silica coating with 30- µm SiO_x‡¶ + silane† application for 5 min

*Conditioner (Dentsply); †ESPE-Sil (3M ESPE); ‡perpendicular to the surface, distance = 10 mm for 20 seconds, pressure = 2.8 bar; §Micro-Etcher (Danville); ¶CoJet-Sand (3M ESPE).

Table 2 Mean Values and SDs of the Bond Strength Results from the Microtensile Bond Strength Test

Group	σ* (MPa) (SD)
1	19.7^b (3.8)
2	10.0^a (2.6)
3	10.4^a (4.0)

*The same superscripted letters indicate no significant difference ($P > .05$).

Materials and Methods

Thirty-four blocks (5 × 5 × 4 mm) of an alumina-reinforced feldspathic ceramic (Vitadur-α, Vita) were fabricated according to the manufacturer's instructions. The ceramic surfaces were finished with a 1,200-grit silicone carbide abrasive. The ceramic blocks were ultrasonically cleaned in distilled water for 3 minutes. Thirty ceramic blocks were randomly divided into 3 surface conditioning groups (Table 1). One additional specimen from each conditioned and nonconditioned specimen was further analyzed under a scanning electron microscope (SEM) for topographic changes.

After surface conditioning, an adhesive system (Single Bond, 3M ESPE) was applied to the ceramic surface, following the manufacturer's recommendations. Resin composite (W3D-Master, Wilcos) was then packed in 3 layers, each 1.5 mm high, onto the conditioned ceramics. Each layer was light polymerized for 40 seconds (XL 3000, 3M ESPE; light output = 500 mW/cm^2) to produce a resin block approximately 4.5 mm high. After storage of the specimens in distilled water at 37°C for 24 hours, the blocks were bonded with cyanoacrylate glue (Super Bonder Gel, Loctite) to a metal base that was coupled with a cutting machine. Slices were obtained using a slow-speed diamond wheel saw (KG Sorensen) under cooling. The peripheral slices were disregarded so that the results would not be influenced by either excess or insufficient amounts of resin cement at the interface. Next, 3 sections, each 0.8 ± 0.1 mm thick, were obtained. Each section was rotated 90 degrees and fixed again to the metal base. The first section was eliminated (± 0.5 mm) for the aforementioned reason and 4 other sections were obtained with 0.8 ± 0.1 mm thickness. Fifteen sticks (nontrimmed beams with an adhesive area of 0.6 mm^2) (sp) were obtained for each block. The ends of each sp were fixed with cyanoacrylate adhesive in an adapted device. A microtensile test was then performed in a universal testing machine (EMIC DL-1000, EMIC) (1 mm/min^{-1}). The bond strength σ (MPa) was calculated according to the formula $\sigma = L/A$, where L is the load for rupture of sp (N) and A is the interfacial area (mm^2) (measured with a digital caliper before testing). The mean bond strength values from the sp of each block (n = 10) were analyzed by 1-way analysis of variance (ANOVA) ($\alpha = .05$) and Tukey test.

The tested sps were further analyzed with SEM (Jeol JSM T330A, Jeol; energy = 15 Kv, WD = 2 mm) (×2,000 magnification), to observe the modes of failure (adhesive, cohesive, or mixed).

Results

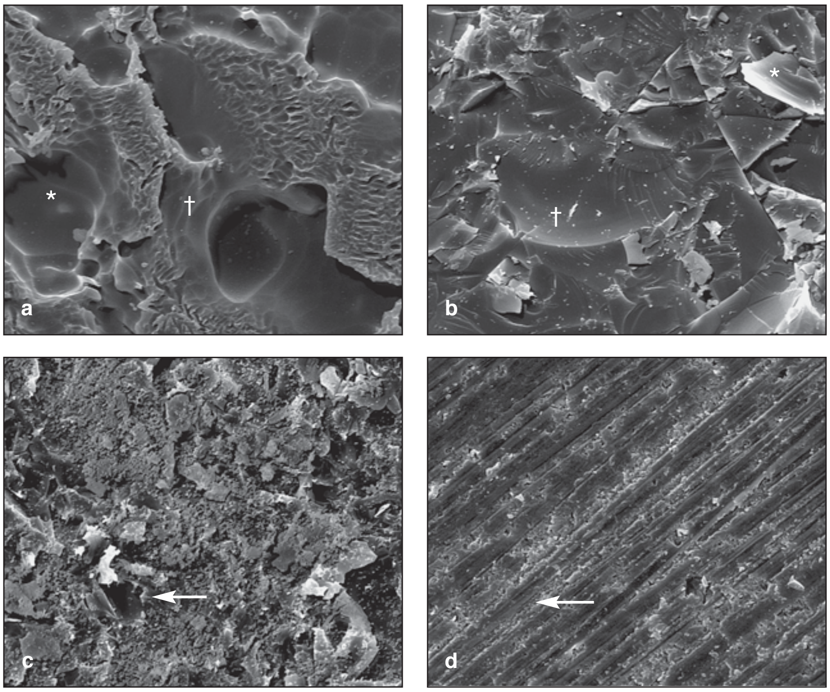
A statistically significant difference was observed between the 3 experimental groups ($P = .00001$) (1-way ANOVA). Group 1 showed the highest mean bond strength, which was significantly higher than those of groups 2 or 3 ($P < .01$). Groups 2 and 3 were not significantly different from each other ($P > .05$) (Tukey post hoc test) (Table 2).

Etching with HF acid appeared to dissolve the glassy phase of the ceramic, creating microporosities that possibly served for micromechanical resin bonding. Air-abraded surfaces were covered with abundant sand particles (Figs 1a to 1d).

SEM analysis of the modes of failure demonstrated predominantly mixed failures in all experimental groups (Table 3). The micrographs representing debonded beams (×100 magnification) are presented in Figs 2a and 2b.

Conclusions

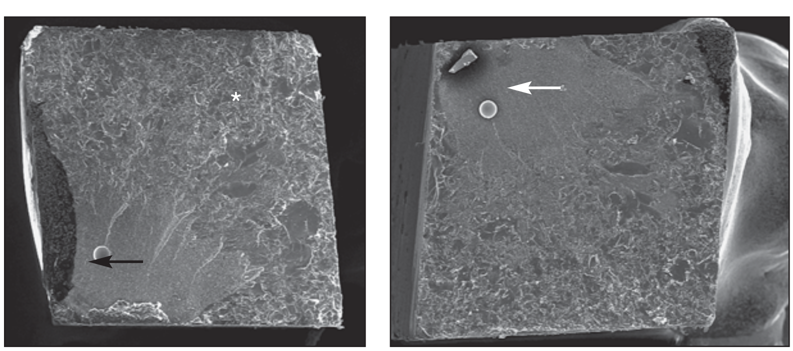
The microtensile bond strength of repair resin to the alumina-reinforced feldspathic ceramic tested in this study was significantly higher after HF acid application and silanization than after airborne particle abrasion either with 110-µm aluminum oxide (Al_2O_3) or 30-µm silicon oxide (SiO_x) followed by silanization.



Figs 1a to 1d Photomicrographs of the conditioned ceramic surfaces (original magnification ×2,000). (**a**) Semicircular craters (*) and peaks (†) after HF acid gel application seemed to contribute to the micromechanical retention of the resin composite. (**b**) Airborne particle–abraded surface with 110-µm Al_2O_3 particles, revealing fixation of Al_2O_3 particles (*) and severe wear of the ceramic surface (†). (**c**) Silica-coated ceramic surface demonstrating deposition of SiO_x *(arrow)* particles on the surface. (**d**) Ground-finished ceramic surface *(arrow)*.

Table 3 Incidence of Failure Types (%) Per Experimental Group

Group	Adhesive	Cohesive	Mixed
1	3	2	95
2	3	3	94
3	5	3	92



Figs 2a and 2b Representative SEM images of the debonded surfaces from a specimen in group 1. The *black arrow* indicates the cohesive fractured surface where most likely the fracture started from an air bubble, leading to major cohesive failure of the ceramic (*). The same group also presented partial adhesive failure in some specimens *(white arrow)*.

References

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