

# Surface Treatments for Tooth-Colored Restorations: Part 2

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Adhesive and restorative success for any indirect restoration begins and ends at the restorative-tooth interface. The bonded restorative complex includes the outer layers of the substrate, the adhesive layer, and the restorative material. Any biomaterial when properly joined to the tooth substrate is able to provide an improved marginal seal while reducing marginal contraction gaps, microleakage, nanoleakage, marginal staining, and secondary caries.<sup>1</sup> Also resulting from the adhesion between tooth and biomaterial is restoration retention and a reduction of stress at the tooth-restorative interface. Biomechanically, this bond reinforces tooth structure and biologically preserves tissues, seals dentin tubules, and provides long-term functional success.<sup>2-4</sup> In part 1 of this article, a discussion of adhesion at the restorative interface was provided to the clinician and technician to encourage more predictable methods for achieving an optimal

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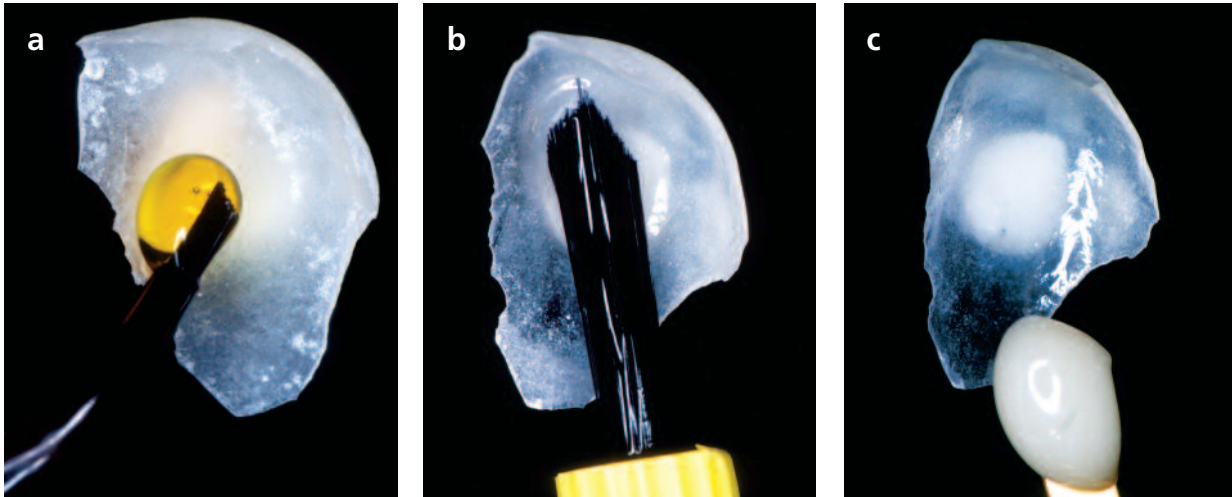
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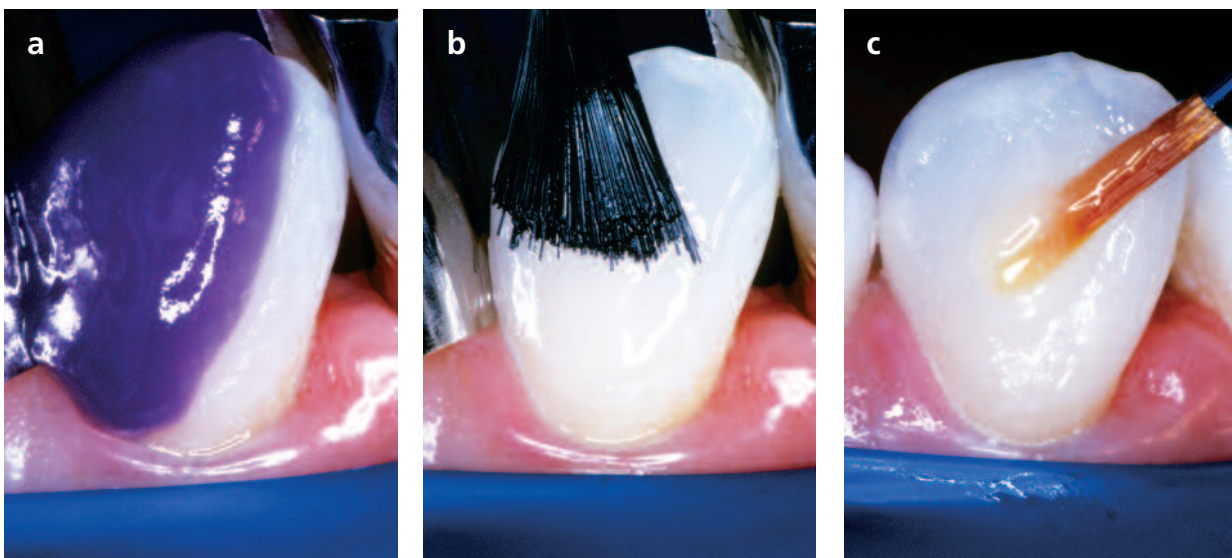


**Figure 1:** The patient presented with no posterior disclusion or anterior guidance after orthodontic treatment. A prepless veneer was placed (tooth No 6) to establish the proper function and to improve the aesthetics.

bonded tooth-colored restoration. As part 1 described a standard surface treatment and adhesive cementation protocol for laboratory-processed composite resin restorations, this segment of the discussion will describe the surface treatment protocols for different ceramic microstructures with various clinical adhesive cementation applications.



**Figure 2:** The internal surface of the silica-based ceramics (Willi Geller Creation, Creation International) was etched with a 9% buffered hydrofluoric acid (Porcelain Etch, Ultradent Products) for 2 minutes, rinsed, and air-dried (2a). An application of silane (Porcelain Bond Activator mixed with Clearfil SE Bond Primer, Kuraray) was applied. Some manufacturers add a silane coupler to their bonding system that is mixed with the other components (eg, bonding agent/primer) during ceramic adhesion (2b). A clear translucent light-cure resin cement (Illusion, BISCO) was applied to the internal surface of the veneer (2c).



**Figure 3:** Once the disinfectant step was completed, the enamel was etched using a 37.5% phosphoric acid (Gel Etchant, Kerr). The gel was placed several mm beyond the anticipated restorative margin (3a). An adhesive agent (Optibond Solo Plus, Kerr) was applied to the etched enamel, air-thinned, and light-cured for 40 seconds (3b). The veneer was positioned into place and the excess resin cement was removed using the "wetbrush" technique and was light-cured for 40 seconds. It is important to leave a residual amount of resin cement at the interface to compensate for polymerization shrinkage (3c).

### Surface treatment of all-ceramic restorations for adhesive resin cementation

Adhesive cementation typically involves surface treatment of the restoration and the tooth structures, application of primers and adhesives and the use of composite resin luting agents. Different ceramic surface treatments have been introduced to pretreat the intaglio ceramic surface and improve the bond at

the ceramic-resin interface.<sup>5-9</sup> The adhesion between ceramic material and composite resins is the result of a physicochemical interaction at the ceramic-resin interface involving 2 simultaneous mechanisms – chemical bonding and micromechanical interlocking.<sup>10</sup> Because of the different chemical structure between silica-based and high-strength ceramics different surface treatments are required.



**Figure 4:** Function and aesthetics were improved using a noninvasive preparation-less procedure.



**Figure 5:** Preoperative facial view of existing ceramo-metal restorations with open margins, recurrent caries, and inadequate epithelial attachment. Patient presents with sensitivity and requests an aesthetic improvement. Treatment required connective tissue grafting and replacement of the existing crowns with zirconium restorations and a Class V composite restoration on the second premolar.

### Silica-based ceramic restorations

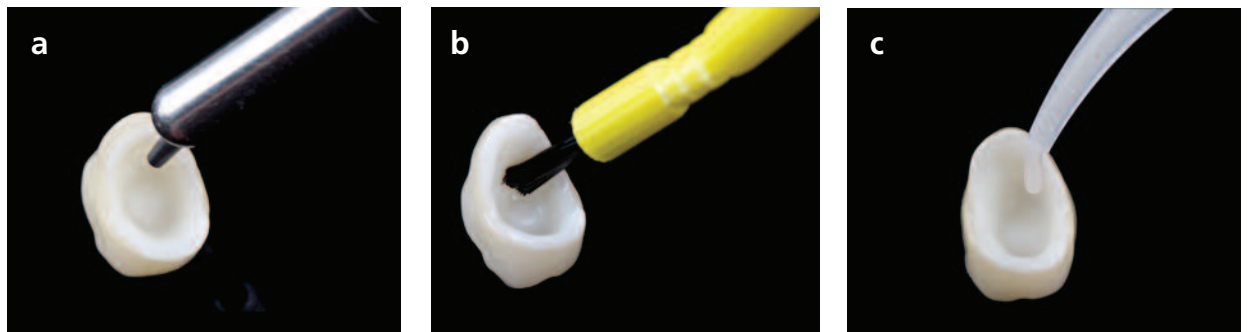
Silica-based ceramic restorations, because of their optical and aesthetic properties, are used to a great extent for porcelain laminate veneers, inlays and onlays, and full-coverage crown restorations. This brittle restorative material derives its strength from the adhesive bond of

the definitive restoration and the supporting tooth structure.<sup>11,12</sup> Proper surface treatment of the ceramic surface prior to cementation is therefore rudimentary for their long-term clinical success.<sup>12,13</sup> Bonding to silica-based ceramics is usually obtained by the 2 aforementioned simultaneous mechanisms.<sup>14-25</sup> The hydrofluoric acid (HF) attacks the glassy phase of the ceramic material, dissolving the surface and exposing the silicate crystals in the matrix, while the silane coupling agents provide a chemical covalent bonding between the silica in the ceramic matrix<sup>20-22</sup> and copolymerizes with the methacrylate groups through siloxane bonds.<sup>26,27</sup> The authors' recommend acid-etching with 4% to 9.8% HF to create surface roughness and the application time depends on the crystalline content of the specific ceramic substrate. A higher crystalline content requires less acid etching time and concentration. A silane coupling agent is then applied to the etched ceramic surface. It is important not to place an excess or thick layer of silane because additional layers of hydrolyzed silane will not bond to the porcelain surface and can result in a less than optimal porcelain bond<sup>28,29</sup> (Figures 1 to 4).

### High strength ceramic restorations

High strength non silica-based ceramic restorations such as zirconia and alumina have increased in utilization by the clinician and technician because of the material's strength, multitude of clinical indications and applications, and its cost effectiveness compared to precious metals.<sup>30</sup> Of course, when preparation designs are retentive, non adhesive cements (ie, glass ionomer cements) or moderately adhesive cements (ie, self-adhesive resin cements) can be used successfully to retain these non silica-based restorations. However, when the retention/resistance form is compromised, adhesive cementation with surface treatment of the ceramic material can improve the durability and reliability of the bond for non silica-based restorations.<sup>30</sup> The excellent optical properties of high-strength ceramic materials are especially advantageous for indirect resin-bonded restorations such as resin-bonded fixed partial dentures. These types of restorations, however, rely on stable and long-term durable resin bonds.

Although the surface treatment for the tooth substrate remains the same (ie, self-etch or total etch), the surface treatment procedures known for silica-based ceramics cannot be utilized for high strength ceramic materials (ie, alumina, zirconia). Traditional bonding procedures (ie, acid etching and silane application) for silica-based



**Figure 6:** The internal surface of the high strength ceramic crown (Lava, 3M ESPE) was microetched using a silica coating, CoJet-Sand (Rocatec/CoJet System, 3M ESPE) (6a). A silane coupling agent (ESPE Sil) was applied onto the internal surface of the restoration (6b). Application of a methacrylate based self-etch cement (G-Cem, GC America) onto the internal aspects of the porcelain crown for final cementation (6c).

ceramics cannot provide long-term durable bonds to the silica-free, acid resistant, high-strength ceramic materials. Conventional acid etchants do not sufficiently roughen the dense surface<sup>31</sup> of these materials and the chemical reaction from silanization of these non silica-based ceramics is not possible. However, silane application can provide increased wettability.<sup>16-27,31,32</sup> Silica/silane coating or application of a phosphate-monomer-containing ceramic priming agent after airborne particle abrasion increases the shear bond strength between zirconium-oxide ceramic and a resin luting agent.<sup>33,34</sup> In addition, several in vitro studies have indicated that air-particle abrasion and a phosphate-modified resin luting agent have the potential to provide long-term durable resin bonds.<sup>35</sup> Another long-term in vitro study found that silica coating and silanization increases resin bond strength to zirconia (Lava, 3M ESPE) with different resin cements.<sup>36,37</sup>

While silica/silane coating failed to provide durable bonds to densely-sintered aluminum-oxide ceramics, it was successfully implemented for zirconia ceramics.<sup>38,39</sup> In an in vitro investigation on the fracture strength and marginal leakage of densely-sintered alumina crowns after aging in an artificial chewing simulator, fracture strengths were well above natural chewing forces for all cementation methods. However, adhesive bonding with a composite resin luting agent and ceramic primer containing adhesive phosphate monomers after air-particle abrasion of the crown intaglio surface significantly increased fracture strength and decreased marginal leakage as compared to conventional cementation methods. The current evidence supports the use of modified priming and/or resin composite luting agents containing special adhesive monomers (eg, MDP Kuraray) that provide chemical bonds to metal oxides and,



**Figure 7:** Postoperative facial view of the final restorations. Notice the soft tissue biocompatibility at the restorative interface.



**Figure 8:** Patient presents with a fractured all-ceramic crown on the maxillary right first molar after endodontic treatment. Treatment involved replacement of existing crown with all-ceramic restoration fabricated with a zirconium internal substructure and Vita surface ceramics (VITA VM9, Vident).



**Figure 9:** The prepared tooth structure was conditioned using a self-etch primer, (ED Primer, Kuraray) and air-dried using a warm air tooth dryer (A-dec).

therefore, long-term durable resin bonds to high-strength ceramic materials.<sup>33-35,38,40-49</sup> Airborne-particle abrasion and an MDP-containing priming agent (Porcelain Bond Activator mixed with Clearfil SE Bond Primer, Kuraray) followed by application of an MDP-containing resin composite luting agent (Panavia F 2.0 [Kuraray]) revealed the highest shear bond strength in one study, although not significantly different from some combinations with Rocatec silica/silane coating.<sup>50</sup>

The authors' surface treatment protocols for high-strength ceramics (ie, aluminum and zirconium oxide) include 2 methods. One method requires silica coating of the inner surface of the restoration with CoJet-Sand (Rocatec/CoJet System, 3M ESPE) followed by an application of a silane coupling agent (ESPE Sil). The application of a silica layer to high-strength ceramics such as zirconia creates binding sites for the silane molecules while the silane provides wettability and a chemical coupling with the methacrylate based cements (Figures 5 to 7). Another user-friendly method involves an application of a commercial primer that contains phosphonate or phosphate monomers. Phosphate monomers form covalent bonds with the zirconia surface and have polymerizable resin terminal ends that copolymerize with the resin cements. The recent developments of several special ceramic primers indicate their importance. Even if a resin cement contains the same adhesive monomer as the priming agent, the primer offers a better wetting effect to the intrinsically rough intaglio surface of an all-ceramic restoration. Currently, there are several ceramic primer systems for zirconia surface preparation available such as Monobond Plus (Ivoclar Vivadent); Clearfil Ceramic Primer (Kuraray); AZ-Primer (Shofu Dental); Metal/Zirconia Primer (Ivoclar Vivadent); and Z-Prime Plus (BISCO) (Figures 8 to 12). Air-particle abrasion with small aluminum oxide particles (eg, 30 µm) before application of a ceramic primer is recommended to further increase bond strengths of composite resins to high-strength ceramic materials.



**Figure 10:** After air-particle abrasion of the internal surface of the restoration with aluminum oxide particles, a zirconium primer (Z-PrimePlus, BISCO) was uniformly applied to wet the internal surface and air-dried for 5 seconds (10a). A self-cure resin cement (Panavia 21TC, Kuraray) was mixed and applied to the internal surface of the crown (10b).



**Figure 11:** The excess cement was removed using a No. 000 sable brush, leaving a residual amount to compensate for polymerization shrinkage (11a). An oxygen inhibitor layer (Oxyguard II, Kuraray) was placed at the interface to accelerate the set of the resin cement (11b).

### Clinical considerations for surface treatment of ceramic material

There are several consideration factors for the surface treatment of ceramic material. First, it is important to avoid contamination of pretreated ceramic surfaces, since organic contaminants such as salivary fluids or finger residue can decrease bond strengths. However, if the restoration is contaminated prior to cementation, any contaminated surface should be cleaned with a phosphoric acid solution for 15 seconds. It is important to remember that different silanes or "ceramic primers" are not the same and, for high-strength ceramics, it is imperative that the priming agent contains special monomers that bond to metal oxides. Conventional silane coupling agents and resin composite luting agents provide excellent long-term durable chemical bonds to silica-based ceramics. Such bonds, however, are not possible to high-strength ceramics that do not contain silica.<sup>42</sup> Also, it is important to remember, that silane coupling agents used for silica-based ceramics can have



**Figure 12:** The completed all-ceramic restoration with a zirconium substructure and Vita surface ceramics (VITA VM9, Vident). Notice the healthy biological framework and the integration of color with the adjacent dentition.

different chemical compositions. However, they must be compatible with the bonding agent and resin cement. Therefore, it is imperative to stay within one bonding system and to closely follow the manufacturer's instructions for application and

timing.<sup>12</sup> In addition, silane coupling agents are dispensed in single or multiple-bottle applications. Single-bottle products typically contain greater amounts of solvents and are, therefore, more susceptible to solvent evaporation, hydrolysis, and polymerization that renders the solution ineffective. Thus, it is essential to periodically review shelf life and remember to seal containers immediately after use. Also, the color of the solution can be a reliable indicator of the efficacy of the solution and if it appears milky, it should be discarded.

### Conclusion

The primary objective of any cementation procedure is to achieve a durable bond and a good adaptation of the luting material to the restoration and the tooth.<sup>51</sup> Conventional cementation techniques for indirect ceramic restorations rely on only one physico-chemical interaction – mechanical interlocking. Adhesive cementation techniques provide a combination of

micromechanical interlocking and true chemical bonding. In addition, adhesive bonding of indirect restorations can increase retention, marginal adaptation, and fracture resistance of the restored tooth and the restorative material when compared to conventional luting techniques. This article has provided the clinician and technician with various alternative materials and techniques for achieving an optimal, long-term, durable adhesive bond to different ceramic microstructures.

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