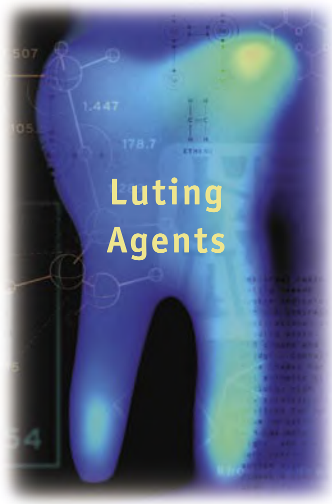


# Selection of Luting Agents: Part 2

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## Introduction

All ceramic restorations are widely used in multiple clinical situations. Bonded porcelain can provide a successful esthetic and functional service for patients. Several clinical studies show excellent long-term success of resin-bonded ceramic restorations, such as inlays and onlays, laminated veneers, and crowns.[1-7] Development of bonding materials, and techniques such as etching and surface conditioning of porcelain are responsible for ceramic restorations becoming a standard treatment in restorative dentistry.[5] Modern adhesive techniques should be used to enhance the strength of ceramic restorations.[8] The clinical success of ceramic restorations depends in part on the use of appropriate cementation procedures, which vary according to ceramic materials.[9,10] As regard to cementation procedures, ceramic restorations can be divided into two groups.[11] One group (conventional ceramic) requires an etching procedure for surface treatment. These include feldspathic porcelain and leucite or lithium-reinforced ceramic (e.g. IPS Empress, Empress II). The other group (high-strength ceramic) requires different treatment to roughen the ceramic surface because conventional acid etching has no positive effect on this group (e.g. glass-infiltrated aluminum oxide ceramic, densely sintered aluminum ceramic, zirconium-reinforced ceramic).[10,12] The composition and physical properties of high-strength ceramic materials, such as aluminum oxide-based ($Al_2O_3$) and zirconium oxide-based ($ZrO_2$) ceramics, differ substantially from silica-based ceramics; therefore they require alternative bonding techniques to achieve a strong, long-term, durable resin bond.[9-11,13]

### Surface Treatments

A reliable resin bond depends on micromechanical interlocking and chemical bonding to the ceramic surface, which requires roughening and cleaning.[14,15] Common surface treatments are acid etching, airborne particle abrasion, silane-coupling agent, and combinations of these methods.[13,15-17]

### Acid Etching

Hydrofluoric acid attacks the glass phase of conventional ceramic materials producing a retentive surface for micromechanical bonding (**Figure 1**).[18]

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**Acknowledgment /** The patient treatment in Figures 7a and b was completed by student Ilya Mironov.

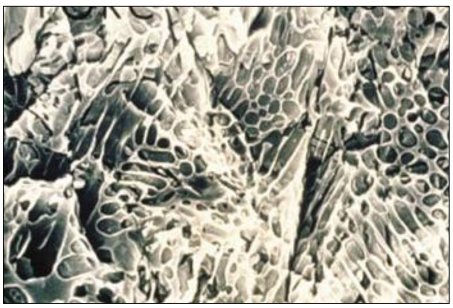

**Figure 1.** Microstructure of etched porcelain.

**Figure 2a.** Congenital missing No. 7.

**Figure 2b.** Feldspathic porcelain-fused-to-metal crown on implant (five-year).

Most laboratories etch the ceramic restoration prior to returning it to the dentist. Following this procedure, the dentist often evaluates the ceramic restoration on the stone cast and additionally performs an intraoral try-in. Contamination of the etched, silanated ceramic with die-stone produces the weakest bond strength and the bond formed is also less reliable.[19] The clinician should always re-etch the ceramic surface with hydrofluoric acid to recreate the micrporous layer in the porcelain free of contaminants. Acid etching with solutions of hydrofluoric acid (HF) can achieve proper surface texture and roughness.[15,20] HF solutions between 2.5 percent and 10 percent applied for one to four minutes seem to be most successful.[15,20] For the leucite-reinforced feldspathic porcelain IPS Empress, and the lithium-disilicate glass-ceramic IPS Empress 2, solutions of 9.6 percent HF applied for two minutes were more successful than APF.[21]

## Silane Coupling Agents

Silane application improves the bond strength of porcelain to composite.[17,21] It improves the wettability of the ceramic and contributes to covalent bond formation between the ceramic and the composite. Etching and silanization significantly decreases microleakage. This is not achieved by silane treatment alone.[22] Silanes are bifunctional molecules that bond silicon dioxide with the OH groups on the ceramic surface, and copolymerizes with the organic matrix of the resin. Airborne particle-abraded silica-based ceramic is not retentive unless a silane coupling agent is also applied.[23]

One-mix and two-mix silanes are available. The one-bottle systems have already been activated. The two-bottle systems are in a nonactive state. One particular concern with the one-bottle systems is that the activated silane has the potential of reacting with itself and can precipitate out of solution. With the one-bottle systems, if the silane appears cloudy or is contaminated, it must not be used. Silane coupling agents contain a high volume of various solvents. Improperly sealed or open containers will allow evaporation of the solvents and increase the concentration of the coupling agent, which may act as a separating medium affecting the bond strength between the ceramic and the composite. The two-bottle systems have an advantage in this regard since the silane is not activated until the time of use.

## Airborne Particle Abrasion and Silica Coating

Ceramic surface treatment is fundamental for bonding to resin. High crystalline ceramics (aluminum and/or zirconium oxides) are poorly conditioned using traditional procedures.[24] In fact, increasing the mechanical strength, by increasing the crystalline content and decreasing the glass content, results in an acid-resistant ceramic whereby any type of acid treatment produces insufficient surface changes for adequate bonding to resin.[21,25,26]

Airborne particle abrasion (110µm aluminum oxide, Rocatec-Pre powder) is used to roughen the internal surface of high strength ceramics.[16] It has been reported that the airborne particles can penetrate up to 15 µm into the ceramic and metal substrates.[27] Use of airborne particle abrasion alone provides insufficient bond strengths.[23] The combination of abrasion and etching produces higher tensile bond strength over etching or abrasion alone.[28] Airborne particle abrasion (100µm abrasive) using Rocatec-Pre (3M ESPE, St. Paul, Minn.) induces chipping or a high loss of silica-based ceramic, and is therefore not recommended for cementation of silica-based ceramic restorations.[16] Further investigation needs to be done on the

**Figure 3.** Empress II onlay on No. 18.

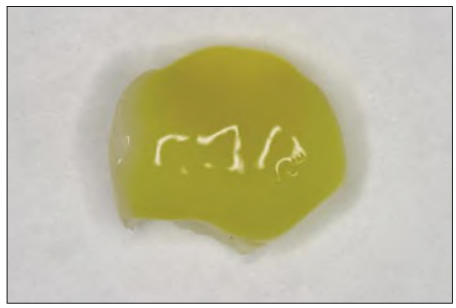

**Figure 4.** Etching with 4-10 percent HF acid for one to three minutes.

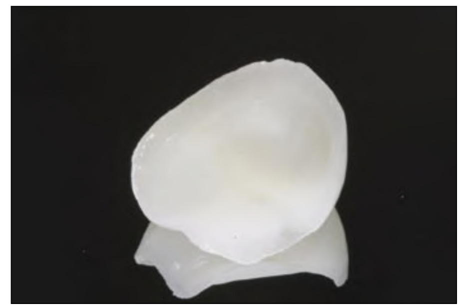

**Figure 5.** Cleaned porcelain surface without ceramic residue.

**Table 1**

**Surface treatment sequence**

| Conventional Ceramic (etchable) | High Strength Ceramic (non-etchable) |
|---|---|
| Etching<br>With 4-10 percent HF acid for 1 to 3 minutes | Microsandblasting |
| ⇩ | ⇩ |
| Rinse with water<br>+<br>Ultrasonic bath in distilled water for 4 minutes | Silica coating (optional) |
| ⇩ | ⇩ |
| Silane<br>+<br>Adhesive luting agent | Adhesive luting agent<br>or other cement |

effect of using less abrasive particle (50 µm or less) on the silica-based ceramic.

Although silica coating systems (e.g. Rocatec, silicoater MD ) were developed for coating of metals, they can improve bonding of resin to glass-infiltrated aluminum oxide ceramic, and densely sintered alumina ceramic.[16,24] The silica coating systems create a silica layer on the ceramic surface because of the high-speed surface impact of the alumina particles modified by silica.[24] The tribochemical silica coating system, which include sandblasting and formation of silica layer, increases tensile bond strength of resin luting cement (Panavia F), and shear bond strength of luting cements (zinc phosphate, glass ionomer, resin-modified glass ionomer, and dual-cured resin cement) on Procera AllCeram (Nobel Biocare, Yorba Linda, Calif.).[24,29]

## Conventional Ceramic (Etchable)

### *Feldspathic Ceramic*

Silica-based ceramics, such as feldspathic porcelain and glass ceramic, are frequently used to veneer metal frameworks (**Figures 2a, b**) or high-strength ceramic copings for all-ceramic restorations due to their excellent esthetic properties.[30] Although the feldspathic ceramic is brittle with low flexural strength by itself, modern adhesive cementation with composite increases the fracture resistance of the ceramic.[31]

### *Reinforced Conventional Ceramic*

Leucite-reinforced feldspathic porcelain (for example: IPS Empress; Ivoclar-Vivadent, Schaan, Liechtenstein) achieves significantly higher fracture strength and can be used to fabricate partial- or full-coverage all-ceramic restorations for both anterior and posterior teeth if resin bonding techniques are properly applied (Figure 3).[32]

A lithium-disilicate glass-ceramic core veneered with a sintered glass-ceramic (for example: IPS Empress 2; Ivoclar-Vivadent) offers further strength that the manufacturer claims permits for the fabrication of short-span fixed partial dentures.[33] Although several manufacturers have marketed their sys-

**Figure 6.** Silane application.

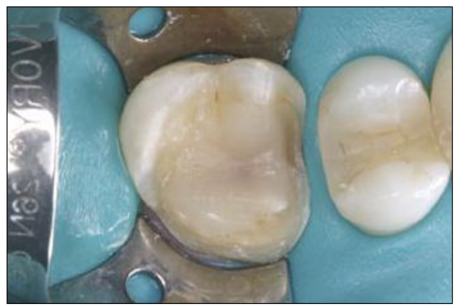

**Figure 7a.** Rubber dam isolation for cementation.

**Figure 7b.** Feldspathic ceramic onlay No. 14.

tem as suitable for the fabrication of all ceramic fixed partial dentures, no long-term clinical trials have verified their efficacy, and further, many anecdotal reports of early failure exist.

*Cementation of Conventional Ceramic*

The ceramic surface should be etched with 4-10 percent HF acid for one to three minutes (**Figure 4**). Following etching, the ceramic work-piece should be rinsed copiously with water. Following etching, ceramic residues often form on the fitting surface of the ceramic. These ceramic residues can compromise the bond strength of the ceramic to the composite. The ceramic restoration should be placed in an ultrasonic bath in distilled water for four minutes. Following cleaning, the ceramic surface should be evaluated to confirm the absence of residues (**Figure 5**). One coat of adhesive resin should be applied to the fitting surface of the restoration following silane application (**Figure 6**), and the restoration should be stored under a light shield to prevent premature curing of adhesive resin (**Table 1**).

Two types of luting agent are used for conventional ceramic materials. These are dual-cured and light-cured resin cement.[1] Light-cured cements have some proven advantages in that working time is increased, the ability to remove excess cement is facilitated, and this reduces finishing time. Dual-cured cements traditionally are used when ceramic thickness do not allow light penetration for maximal conversion of the luting cement. With thick ceramics, light-cured cements do not reach a level of microhardness of maximum cure.[34] Disadvantages of dual-cured cements include porosity from mixing, reduced working time, decreased degree of conversion, and color instability due to amine degradation. Light-cured cements can be safely used under ceramic restoration with less than 3 mm thickness (**Figures 7a, b**).[34]

## High Strength Ceramic (Non-etchable)

*Glass-infiltrated Aluminum-Oxide Ceramic*

With the increase of aluminum oxide content ($Al_2O_3$) in feldspathic ceramics, there has been a significant improvement in the mechanical properties (flexural strength of 450 MPa) of In-Ceram Alumina, allowing metal-free restorations to be used more predictably.[35] Due to the low silica content, acid etchants used for conventional ceramics do not sufficiently roughen the surface of aluminum-oxide ceramics.[9] Airborne particle abrasion with aluminum oxide is effective to roughen this ceramic surface.[16] The application of silica coating on this ceramic also has been recommended.[16]

*Densely Sintered Aluminum-Oxide Ceramic*

Procera AllCeram (Nobel Biocare, Yorba Linda, Calif.) is a high-strength ceramic material (flexural strength of 610 MPa) with a highly dense, sintered $Al_2O_3$ content (99.9 percent of $Al_2O_3$), with a negligible glassy phase.[36] Procera AllCeram crowns have proved to be a reliable choice for the restoration of anterior teeth on both natural and implant-supported abutments.[37] Tribochemical silica coating systems increase the tensile bond strength values between Panavia F (Kuraray, New York, N.Y.) and Procera AllCeram ceramic.[24] Sandblasting alters the surface of densely sintered alumina more effectively for increased bond strengths than do conventional acid-etching and grinding.[13] The use of a retentive preparation design is indicated to obtain greater

**Figure 8.** Procera crowns before surface treatment.

**Figure 9.** Microsandblasting with 50µm $Al_2O_3$ particles.

**Figure 10.** Left-side crown shows inner surface after microsandblast, compared to surface before sandblast on right side.

retention of alumina-reinforced ceramic systems.[26] Clinical studies show that the hybrid glass ionomer cement, and resin cement could be a choice of luting agent of these restorations.[12,37]

*Zirconium Oxide Ceramic*

The clinical use of zirconium oxide ($ZrO_2$) as a core material has advantages, including a high flexural strength of over 1000 MPa.[38] Polycrystalline $ZrO_2$ is typically used in a tetragonal crystalline phase, partially stabilized with yttrium oxide. A unique property is the so-called ''transformation toughening,'' where a partially stabilized zirconium oxide can actively resist crack propagation through a transformation from a tetragonal to a monoclinic phase at the tip of a crack, which is accompanied by a volume increase.[39] Due to the high strength, zirconium oxide ceramics are considered for use in multiple restorative procedures, including endodontic dowels, implant abutments, full-coverage crowns, and resin-bonded FPDs.

*Cementation of High Strength Ceramic*

Since these high-strength ceramics are not etchable, retentive preparations and alternative surface treatments are fundamental for predictable long-term success (**Figure 8**). Several studies show sandblasting with 50µm $Al_2O_3$ particles creates a good micromechanical roughened surface for high-strength ceramics (**Figures 9, 10**). Luting agents for these restorations include phosphate-monomer-containing resin cement, conventional resin cement, resin-modified glass ionomer cement, glass ionomer cement or zinc phosphate cement. Recently, self-etching, adhesive cements (e.g. Max-Cem [Sybron/Kerr], Rely-X Unicem [3M/Espe], Universal Resin Cement [Pulpdent]) have been developed. There are several "in vitro" studies showing their effectiveness, but there is no long-term clinical study available now and their "adhesive" properties have not been investigated completely yet. The clinical success of high -strength ceramic restoration does not rely on the resin bond to the crown, even though some authors have concluded that, based on the current evidence, adhesive cementation procedures are necessary to support all-ceramic materials (**Table 1**).[40]

## Summary

All-ceramic restorations are becoming increasingly important in contemporary esthetic restorative dentistry. There has been a considerable introduction of diverse all-ceramic restorative materials in recent years. Long-term clinical success is often dependent on use of the most appropriate cementation protocol. This includes optimum surface treatment of the ceramic as well as proper choice and manipulation of the luting agent.

This article has classified available all-ceramic materials and provided recommendations for optimum surface treatment and choice of luting agent. The clinician is cautioned that it is imperative to understand the nature of any all-ceramic system that may be utilized so that optimum surface treatment and luting agents can be utilized. CDA


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