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# A comprehensive review on bonding between monolithic ceramics and tooth structure with different adhesive agents

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## Abstract

Reliable bonding between the prepared tooth and monolithic ceramics can be achieved by various luting agents available on the market. The selection of luting agent and cementation technique plays an important role in the success of the restoration. With the advent of resin-based adhesive systems as luting agents, clinicians' perspectives have changed to a more conservative approach. Recent systems, chemically adhere the crowns to the prepared tooth structure showing higher bond strength. To reach the aesthetic demands of the patients, all-ceramic restorations were considered over metal-ceramic crowns. Few all-ceramic crowns are brittle, the strength is dependent on the chemical structure and method of fabrication. While some all-ceramic restorations gain strength after cementation. Thus, the choice of luting agent used in cementing all-ceramic crowns is crucial. Even though many luting agents are being introduced no single luting agent fulfilled all the requirements. Among them, adhesive cements showed greater bond strength and enhanced the retention of minimal preparation, which are less retentive. Traditional non-adhesive agents can be used in retentive preparations that bond through mechanical means rather than the chemical bond seen in newer adhesive cements. Also, surface treatments of zirconia showed greater bond strengths irrespective of the luting agent being used. These include air abrasion, acid etching, applying silane couplers, and primers that increase the surface area for adhesion. The use of all-ceramic restorations, the need for surface treatments, types of surface treatments, adhesion and adhesive agents, and evidence from current *in vitro* research on monolithic ceramics and tooth adhesion were all discussed in this review.

**Keywords:** Bond Strength, Adhesive agents, All-Ceramics, Monolithic Ceramics, Zirconia, Tooth.

## 1. Introduction

All-ceramic dental restorations have gained popularity in recent years as a result of the growing focus on aesthetic restorations. They have a highly aesthetic appearance and metal-free structure, which led them as anterior or aesthetic restorative material of choice. Even though all-ceramic restorations used as single crowns and short-span fixed partial dentures (FPDs) had shown resistance to occlusal forces their use is limited in treating long-span edentulous areas [1]. Nowadays, most dentists and patients prefer ceramics over metal or metal-ceramic restorations. Treatment success is determined not only by case selection, tooth preparation, manufacture, and kind of ceramics but also by the luting agent utilised and the technique employed for cementing the ceramic prosthesis [2]. However, compared to traditional cements, the resin-based systems show the bonding between a tooth and the restoration improving the retention, marginal adaptation, and fracture resistance of restorations [3]. In order to achieve adhesion between a luting agent and a ceramic surface requires surface pre-treatment with various materials.

## 2. Discussion

### 2.1 All- ceramic materials

All-ceramic restorations include inlays, onlays, veneers, and crowns, which can be used as single or multi-unit restorations. Because of their excellent colour matching with natural teeth, they are extremely attractive restorative materials. Despite this, there is a lack of strength and difficulties in achieving a satisfactory internal and marginal fit due to the manufacturing process. All-ceramic restorations can be fabricated in a dental lab or dental office [1]. Laboratory-produced restorations provide a better internal fit than in-office milling restorations. The milling procedure, on the other hand, has the advantage of being able to accomplish the aesthetic restoration in a single session without the requirement for an interim restoration [4].

Recent research has focused on either veneering high-strength alumina, zirconia, spinel, or lithium disilicate core with more translucent porcelain or employing a leucite-reinforced translucent material to enhance the strength of aesthetic restorations.

#### *2.1.1 Monolithic ceramic crowns*

Monolithic aesthetic restorations are the strongest ceramic restorations, while coloured monolithic zirconia crowns can be used on the back teeth. They are suitable in situations when interocclusal space is limited due to their capacity to withstand heavy loads during mastication. Complete ceramic restorations can be fabricated using an indirect technique. The etchable crown internal surface is acid-etched and luted with composite resin to produce retention keys [5].

#### *2.1.2 Ceramic Inlays and Onlays*

Ceramic inlays and onlays are more durable due to their high abrasion resistance when compared to posterior resin composites. Thus, grinding ceramic is more difficult for occlusal adjustments and can lead to subsequent wear of the opposing tooth if not properly adjusted and polished. Although the marginal gap greater than with gold inlays or onlays is within the clinically acceptable range [6].

Ceramic inlays can be fabricated in different ways and with various materials, but computer-aided design and manufacturing (CAD/CAM) is used more than manual casting or pressing techniques [1,4]. The best-known system is Cerec (Siemens), which has been in use for a decade. Denzir (Dentronic), the recent method to fabricate inlays with zirconia as ceramic material uses laser light scanning of a working die from an impression, then milling the inlay.

Ceramic inlays can be luted to a prepared tooth with adhesive resin cements that are recently available on market. Compared to conventional zinc phosphate cements, adhesive resin cements have low solubility, and good aesthetic properties, and the adhesion increases the functional strength of inlays [2,3]. Etching the inner surface of a crown or inlay with hydrofluoric acid followed by the application of a silane varnish is a recommended method [7].

#### *2.1.3 Ceramic Veneers*

A ceramic esthetic veneer is also known as the laminate veneer is a layer of ceramic that is bonded to the buccal or labial surface of the prepared tooth in order to cover an unsightly area. They are usually customised for individuals and fabricated in the dental laboratory. They gained popularity soon because tooth preparation is more conservative, and the restorations are esthetic. Earlier, they are manufactured by sintering feldspathic porcelain [1].

Recently, most ceramic veneers are fabricated by heat-pressing or machining, using either a leucite reinforced or lithium-disilicate ceramic. Although, an *in vitro* study demonstrated some disadvantages related to marginal adaptation and bonding problems. Numerous studies described the bonding of porcelain laminate veneers to acid-etched enamel by both clinical and laboratory procedures [8].

Traditionally, etching the enamel surface with ortho-phosphoric acid, proposed by Buonocore *et al.*, is commonly used to increase the bond strength between the composite and enamel. This etching technique creates an irregular surface on enamel allowing an increase in the prepared surface area available for the retention of the composite. Thus, the marginal adaptation of laminate veneers. The retentive characteristics of acid conditioned enamel surfaces are determined by the type of acid, etching time, and chemical composition of enamel. The tooth enamel is etched with phosphoric acid, and the bonding surface of the ceramic is etched with hydrofluoric acid gel (5% to 9%) before being treated with a silane coupling agent to ensure appropriate adhesion. Resin composites are designed specifically for bonding to ceramic adhesives [6].

Laser etching can be considered to be a viable alternative to acid etching of enamel and dentin as it is painless and does not produce vibration or heat. Also, laser etching of enamel or dentin has been reported to obtain fractured and uneven surfaces and open dentinal tubules that are ideal requirements for adhesion [8].

### 2.2 Surface treatments

Treatment success of resin-bonded all-ceramic restorations is dependent on bond durability and reliability. The bond is usually obtained by micromechanical retention with hydrofluoric acid etching and/or grit blasting, followed by chemical bonding by a silane coupling agent [9]. Konakanchi A *et al.*, in 2017 [10] described the chemistry, mechanism and applications of silane coupling agents in a review stating they can be used in ceramic repair with composites to enhance their bonding. Etching the inner surface of a restoration with hydrofluoric acid followed by the application of a silane coupling agent increases the bond strength [11-13].

#### *2.2.1 Need for surface treatments*

Shimada Y *et al.*, [14] demonstrated that hydrofluoric acid etching glass-ceramics adversely affect the ceramic bond. Numerous studies have shown that the newer generation ceramic primers could strongly bond to machinable glass-ceramics without grit blasting or etching the ceramic surface with hydrofluoric acid. Many studies have shown that adhesive composite resin cements increase the fracture resistance of glass-ceramic restorations, providing high retention, improving marginal adaptation and preventing microleakage by penetrating surface flaws and irregularities and inhibiting crack propagation. Fracture resistance of the ceramic–resin bond is mainly controlled by surface treatment of the ceramic along with the microstructure. Hooshmand T *et al.*, [15] and Aida M *et al.*, [16] concluded that elimination of the acid etching stage with hydrofluoric acid in the bonding procedure is possible. Sorensen JA *et al.*, [17] reported that using a silane coupling agent has no beneficial effect. Therefore, an optimal bonding protocol must be developed [11].

#### *2.2.2 Surface treatments*

The surface treatments are mainly divided into two bonding techniques that are micromechanical bonding techniques and chemical bonding techniques [18]. The micromechanical bonding techniques are further divided into mechanical treatment and chemical treatments. Mechanical treatments include airborne-particle abrasion; tribochemical silica coating; Diamond and disk grinding; zirconia particle suspension; electrical machine discharge; Laser (CO2 laser, Nd:YAG and Er:YAG lasers) [18,19].

Various acid solutions, such as HCl, HF, and others, are used in chemical treatments. Chemical bonding techniques are categorized into two groups: silicon coatings and coupling agents. Tribochemical silica-coating, porcelain-coating, and magnetic sputtering vapour deposition are examples of silicone coatings. Silanes, zirconia, and metal primers (10-MDP, Z primer, and others) are employed as coupling agents [18].

### 2.3 Adhesion between the tooth and monolithic ceramics

As compared to other clinical procedures, the cementation process is underappreciated, although it can improve bonding in minimal and less retentive situations, resulting in a successful restoration. The adhesive bonding must be taken into consideration when inlays, onlays, and short or over-tapered crown preparations; veneers, overlays (“vonlays”), and Maryland bridges are to be cemented.

#### *2.3.1 Adhesion*

Proper knowledge of adhesive principles and adherence to the clinical protocol helps to achieve a bond between the tooth structure and adhesive cement. The adhesive bond between the tooth and the restorations can stabilize ceramic restorations, resulting in higher resistance to the external forces. Because adhesives have lower mechanical strength than ceramics, more attention was given to the behaviour of the adhesive contact.

#### *2.3.2 Adhesive agents*

For some dental ceramics, ceram¬ic restoration bonded to tooth structure reinforces the restoration. To transfer force to the underlying tooth, Feldspathic porcelain should be effectively bonded to the tooth structure to transfer force to the underlying tooth. Particle-abraded zirconia ceramics should be primed with a 10-methacryloxydecyl dihydrogen phosphate (MDP) solution [20].

Resin cements are available in self-cure, light-cure, and dual-cure modes. Light-cure resin cements offer increased working time and cure on demand, which is particularly beneficial for ceramic veneers. Dual- and self-cure resin cements are used in thick or opaque restorations where light cannot penetrate the restoration to cure the cement [21].

However, zirconia cementation remains a challenge with adhesive and non-adhesive luting cements. Most investigations have concluded that the composite resin cements create a stronger bond between dentin and zirconia ceramics. Resin cements containing a functional phosphate monomer, commonly known as silane or 10-methacryloyloxydecyl dihydrogen phosphate, demonstrated both short- and long-term bonding to air-abraded zirconia. This approach is now thought to be the most reliable technique for cementing high-density ceramics and zirconia [22]. For retentive tooth preparations, conventional non adhesive luting agents can be used.

#### *2.3.3 Bond strength*

Various surface treatments of zirconia ceramics, such as airborne-particle abrasion (APA) and tribochemical silica coating (TBC), have been recommended to improve the bond strength between zirconia ceramics and the luting agent [23,24]. APA improves bond strength through micromechanical interlocking, whereas TBC improves bond strength through a combination of surface roughening and chemical bonding. Shear bond strength (SBS) and tensile bond strength (TBS) tests have been used to evaluate the bond strength of different ceramic materials [25].

Adequate adhesion between resin cement and a zirconia prosthesis results in increased retention, reduced microleakage and increased fracture resistance. Kim *et al.*, reported that the Shear Bond Strength between resin cement and colored zirconia made with metal chloride was improved with zirconia primer. Also, immersion in an aqueous molybdenum chloride solution is recommended for sufficient resin bonding to zirconia [26].

Kumbuloglu O *et al.*, [27] comparatively studied the shear bond strength of different commercial composite resin cement systems to lithium disilicate all-ceramic substrate. Five adhesive resin cement systems included in the study were RelyX Unicem Applicap and RelyX ARC (3M ESPE), Panavia 21 and Panavia F (Kuraray), Variolink 2 (Ivoclar-Vivadent) and all-ceramic (IPS Empress 2; Ivoclar-Vivadent) substrate was used to evaluate the shear bond strength. Testing the shear bond strength of adhesive resin cement to substrate was carried out with or without the thermocycling process. Panavia F subgroup showed higher bond strength values than Panavia [22]. Also, a decrease in bond strength with thermocycling is seen.

Stewart GP *et al.*, [28] conducted an *in vitro* study to evaluate shear bond strengths immediately and after six months between a feldspathic ceramic and four different resin cements (Nexus, Panavia 21, RelyX ARC, and Calibra). In this study, six different surface-conditioning treatments were done using sanding with 600-grit silicon carbide paper, micro-etching with aluminum oxide, silane application after sanding, micro-etching and silane application, hydrofluoric acid etching, and hydrofluoric acid etching before applying the silane agent. Results showed that Shear bond strengths between the four resin cements and the dentin also were measured using hydrofluoric acid etching followed by silane application produced the best bonds at 24 hours and six months with all four cements. Auto-polymerized and lightpolymerized adhesives demonstrated higher bond strengths to dentin when compared to dual-polymerized adhesives.

Chang JC *et al.*, [29] investigated the tensile bond strengths of 5 luting agents namely Vita Cerec Duo Cement, EnForce, Panavia 21, C&B Metabond, and Fuji Duet. to 2 CAD-CAM restorative materials (Dicor MGC, Cerec Vitablocs Mark II) and enamel. This study suggested that EnForce and Panavia may be recommended for cementation of Dicor MGC crowns; and Fuji Duet, EnForce, C&B Metabond, and Cerec Duo may be recommended for cementation of Cerec Vitablocs Mark II. The higher tensile bond strengths were observed with Cerec Vitablocs Mark II when compared to Dicor MGC. Therefore, Cerec Vitablocs Mark II can be considered the material of choice for CAD-CAM crowns.

### 2.4 *In vitro* studies

Woo ES *et al.*, [30] compared the Shear Bond Strength of self-adhesive auto-polymerized resin cement and a dual-cure adhesive resin cement (DPRC) with the different layers of a monolithic polychromatic $ZrO_2$ ceramic. The results showed that for the $ZrO_2$ cubic and tetragonal layers, the DPRC had higher bond strengths than the nonglazed surfaces. They concluded that the resin cements are suitable luting agents for $ZrO_2$ restorations.

Tzanakakis EG *et al.*, [31] evaluated the effect of water storage on the hardness and interfacial strength of three CLA, a non-adhesive (Multilink Automix/ML), an adhesive (Panavia F 2.0/PF) and a self-adhesive (PermaCem 2.0/PC), bonded to polished (CL) and grit-blasted (AL: 50 μm alumina, SJ: Sil-Jet + Monobond Plus silane) monolithic zirconia surfaces. The results showed that hardness is higher in adhesive-free luting agents. Also, Tribo-chemical silica coating combined with a silane coupling agent containing phosphate/ disulfide monomers was the most efficient bonding treatment for the non-adhesive and the self-adhesive luting agents. While the adhesive luting agents were the best treatments for alumina grit-blasted zirconia [32].

Chirca O *et al.*, [33] conducted a Finite Element Analysis simulation and Scanning Electron Microscope investigation upon the inlay and onlay restoration structures. Various conclusions drawn from this study were;

- The adhesion between the restorations and the tooth structure can stabilize the ceramic restorations, resulting in higher resistance to the action of external forces.
- The adhesive cement/restoration interface seems to be more difficult to achieve in inlay; self-adhesive and universal cements seem to be more efficient in onlay type restorations.
- The adhesive cement/dental structure interface is much more efficient for all types of cementing techniques and various designs.

Altan B *et al.*, [34] compared shear bond strength between 2 brands of monolithic zirconia blocks (Vita YZ HT, Sirona inCoris TZI), yttrium-stabilized tetragonal zirconia (IPS e.max ZirCAD) and zirconia-reinforced lithium silicate ceramic (Vita Suprinity) which were divided into six groups according to the surface treatment received: a) no treatment (control), b) HF acid etching, c) sandblasting, d) sandblasting + Er:YAG laser irradiation, e) Er:YAG laser irradiation and f) CoJet. A self-adhesive resin cement (Theracem) was used for the bonding of composite resin cylinders to the ceramic blocks, and the shear bond strength was evaluated after thermocycling. Higher bond strength values were seen in Monolithic zirconia blocks than in Y-TZP zirconia blocks in both sandblasting and CoJet groups. HF acid etching is more effective when compared to sandblasting and CoJet for Vita Suprinity.

## 3. Conclusion

Current ceramic bonding systems are based on micromechanical b0nding between cement and ceramic restorations. Porcelain surface preparations for mechanical retention include grinding, sandblasting, and etching with acids. Bonding strategies for monolithic zirconia restorations could potentially benefit from Immediate Dentin Sealing, regardless of the adhesive luting agent system used. Moreover, MDP-containing luting agents are more effective when combined with airborne particle abrasion. The application of silane coupling agents (primer) creates a chemical surface preparation that aids in the enhanced porcelain bond strength. However, it has been shown that silica coating followed by silanization can be used to improve the bond strength for silica-based, glass-infiltrated alumina and zirconium ceramics.

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