Bonding of Resin Materials to All-Ceramics: A Review

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Abstract: Problem statement: All-ceramic materials, especially silica-based lithium disilicate and non-silicate-based Zirconia, have become a topic of interest in the field of dentistry. It is still difficult to achieve a strong and durable resin-ceramic adhesion, especially resin-Zirconia bonding. **Approach:** The article reviews the current literature published in the past 5 years, focusing on the latest resin bonding techniques (including surface treatment, priming and cementation) for dental all-ceramic materials, especially Zirconia and lithium disilicate ceramics. A search of dental literature from PubMed and MEDLINE databases was conducted and the key words included Zirconia, lithium disilicate and bond. Titles and abstracts of the articles listed from search results were reviewed and evaluated for appropriateness. **Results:** The literature demonstrates that a variety of surface roughness, priming and cementation methods are available for improving resin-ceramic bonding. **Conclusion:** Available data suggest that the preferred bonding methods for silica-based ceramics are hydrofluoric acid-etching and subsequent silent treatments. The preferred protocol for Zirconia-resin bonding is the combination of surface roughness such as air-abrasion and treatment with a phosphate-containing Zirconia primer followed by cementation with a non-phosphate-containing resin cement.

Key words: Zirconia, lithium disilicate, surface treatment, phosphate monomer, primer

INTRODUCTION

There has been an increasing interest and demand in the use of all-ceramic materials due to their non-metallic, biocompatible and improved esthetic features (Blatz *et al*., 2003; Conrad *et al*., 2007). The core materials of all-ceramics include silica-based glass ceramics, such as Lithium-disilicate ($2SiO_2-Li_2O$), Leucite ($SiO_2-Al_2O_3-K_2O$) and Feldspathic ($SiO_2-Al_2O_3-Na_2O-K_2O$) and silica-free high strength ceramics, such as Zirconia (ZrO_2) and Alumina (Al_2O_3) (Conrad *et al*., 2007). Among the all-ceramic materials, Zirconia and lithium disilicate have been becoming the most popular materials in the dentistry, due to their improved mechanical strengths (Conrad *et al*., 2007). For instance, among the 600 thousands all-ceramic restorations fabricated by Glidewell Laboratories in 2011, 75% are Zirconia ceramics, 23% are lithium disilicate and only less than 2% are leucite-reinforced other ceramics.

A strong and durable resin-ceramic bond improves marginal adaptation and provides high retention (Blatz *et al*., 2003). The resin-ceramic bonding procedure includes surface treatment/roughness (mechanical bonding) and/or priming (chemical bonding) and cementation with resin cements. Blatz *et al*. (2003)

reviewed the resin-ceramic bonding based on the literature published from 1966-2001, while Conrad *et al*. (2007) have a systematic review covering all-ceramics, with respect to survival, material properties, cementation and clinical recommendation based on the literature published between 1996 and 2006. Thompson *et al*. (2011) reviewed the cementation to Zirconia based on the literatures published before 2009. During the past several years, new ceramic materials, such as IPS e. max Press lithium disilicate (Ivoclar Vivadent) (Conrad *et al*., 2007) and new bonding techniques/primers, such as phosphate-containing Zirconia primers, have been developed (Attia and Kern, 2011a; Ikemura *et al*., 2011a; Magne *et al.,* 2010). This review will cover primarily the literature from 2008-2012, focusing on the latest resin bonding techniques (including surface treatment, priming and cementation) for dental all-ceramic materials, especially the two dominant materials Zirconia and lithium disilicate ceramics.

MATERIALS AND METHODS

A search of English peer-reviewed dental literature from PubMed and MEDLINE databases was conducted and limited to the publications between the years 2008

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and 2012. Key words included Zirconia, lithium disilicate and bond. Titles and abstracts of the articles listed from search results were reviewed and evaluated for appropriateness.

RESULTS

A total of 300 articles was identified through the literature search and 186 articles were published between 2008 and 2012. The abstracts of articles were reviewed and evaluated and a total of 101 articles were relevant to re-sign-ceramic bonding. The literature demonstrates that a variety of surface roughness, priming and cementation methods are available for improving resin-ceramic bonding.

DISCUSSION

Lithium disilicate and Zirconia ceramics: Lithium disilicate ($2SiO_2$-Li_2O), such as IPS e. max (Ivoclar Vivadent) which is available as an ingot and block, can be processed using the lost-wax hot pressing techniques (ingot, IPS e. max press) or state-of-the-art computer-aided design/computer-aided manufacturing (CAD/CAM) milling procedure (block, IPS e. max CAD) (Fasbinder *et al*., 2010). It can be used for anterior/posterior crowns, inlays/onlays, veneers, implants and fixed partial denture prosthesis frameworks The pre-crystallized blocks or ingots are milled to the desired form by CAD/CAM or pressing techniques and the final crystallization occurred at 850°C (CAD/CAM) or 920°C (Pressing) under vacuum (Fasbinder *et al*., 2010; Conrad *et al*., 2007). Lithium disilicate glass ceramics have improved physical properties compared to other glass ceramics. The IPS e. max glass ceramic has a flexural strength of 360-500 MPa, which is more than twice greater than that of other glass ceramic monolithic materials (Fasbinder *et al*., 2010).

Zirconia or Zirconium Oxide (ZrO_2), is a polymorphic white crystalline material that occurs in three crystallographic forms. It has a monoclinic crystal structure at room temperature, tetragonal between 1170 and the 2370°C and cubic structure above 2370°C (up to its melting point of 2680°C) (Denry and Kelly, 2008). The phase transformations from cubic to tetragonal and from tetragonal to monoclinic occur upon cooling and are accompanied by volume expansions (2.3% for cubic-to-tetragonal and 4.5% for tetragonal-to-monoclinic), which induce very large internal stresses. A small amount of lower valence oxide (e.g., Magnesium oxide, yttrium oxide, calcium oxide) is added to pure Zirconia to control the volume expansion

and stabilize Zirconia in its tetragonal phase at room temperature (Conrad *et al*., 2007). Examples of dental zirconia include yttria (Y_2O_3) stabilized tetragonal zirconia polycrystals (Y-TZP), which usually contain 3 mol% of yttria as a stabilizer (3Y-TZP), such as Lava (3M ESPE), Cercon (Dentsply) and DC Zircon (DSC Precident), zirconia-toughened alumina (e.g. In-Ceram Zirconia, Vita) and magnesia partially stabilized Zirconia (e.g. Denzir-M, Dentronic AB). Y-TZP can be manufactured through CAD/CAM techniques. First, an enlarged framework is designed and milled from pre-sintered soft block. Then the soft zirconia is sintered between 1350 and 1550°C. The Zirconia framework has a linear shrinkage 20-25% during the sintering (Conrad *et al*., 2007). Y-TZP has excellent mechanical properties, such as high flexural strength (~1000 MPa), high fracture toughness (6-8 MPa $m^{1/2}$), low friction coefficient (0.028-0.082) (Szpiro *et al*., 2008). Dental Zirconia ceramics can be used for crowns, cores, posts, implants, onlays, fixed partial denture prosthesis frameworks.

Surface Treatments:

Silica-based ceramics: A reliable and effective resin-ceramic bond depends on mechanical and chemical bonding (Blatz *et al*., 2003) which are created through mechanical interlocking from surface roughening and from the chemical reaction of resin materials (e.g. Primers) and ceramics, respectively. Mechanical bonding/interlocking is created through infiltration of adhesive into highly micro-retentive substrates. Common surface treatment methods for creating micro-retentive ceramic surfaces include grinding, air-abrasion with alumina, acid etching and the combinations of any of these methods.

For the glass ceramics which contain various amounts of glass/silica compositions, such as lithium disilicate, etching with 4-9.5% hydrofluoric acid has been proven a successful surface treatment method to provide surface roughness for mechanical interlocking/bonding (Blatz *et al*., 2003; Conrad *et al*., 2007). Among different surface treatments, such as phosphoric or HF acid etching and air-abrasion with alumina, etching with hydrofluoric acid was the most effective in enhancing the bond strength of resin material to lithium-disilicate ceramics (Nagai *et al*., 2005; Panah *et al*., 2008; Brum *et al*., 2011). Lithium-disilicate IPS e. max CAD had the highest bond strength when it was the HF-etched after machined, compared to being machined only or machined/grit blasted (Pollington *et al*., 2010). It seemed that laser etching (Er: YAG laser; wavelength: 2940 nm) with an appropriate power setting (300 mJ) could also be used for surface treatment of lithium disilicate and could be

as effective as hydrofluoric acid etching (Gokce *et al*., 2007).

Contaminations, such as saliva, blood and hydrogen peroxide, influenced the bonding between dentin and lithium disilicate ceramics, while desensitize and disinfectant had no negative effects on the bond strengths (Zortuk *et al*., 2010). Among 4 different cleaning methods (etching with 37% phosphoric acid, etching 5% hydrofluoric acid, 96% isopropanol, air polishing device with sodium bicarbonate), re-etching with hydrofluoric acid is the most effective in removing lithium duplicates contamination with saliva and/or a silicone disclosing medium (Klosa *et al*., 2009). Hydrofluoric acid-etched silica-based ceramic has a highly retentive high-energy surface which is highly contaminable. The try-in pastes on etched ceramics (before silane treatment) are very difficult to remove. Studies on the efficacy of 'Try-in' paste removal showed all of etched lithium disilicates had remaining particles of try-in pastes, after cleaning by different methods, such as an ultrasonic bath in distilled water, air/water spray, etch with phosphoric acid plus an air / water spray, or etch with phosphoric acid before and after hydrofluoric acid application plus air/water spray (Prata *et al*., 2011).

Non-silica-based ceramics (Zirconia): Zirconia has a silica-free surface and HF-etching is not effective for changing Zirconia's morphology microstructure (Borges *et al*., 2003). Airborne particle abrasion with alumina or grinding creates surface roughening and significantly improved Zirconia-resin bond strength (Blatz *et al*., 2007). However, excess grinding or air-abrasion might promote Zirconia degradation (Sato *et al*., 2008). In recent years, many other surface treatment techniques have been explored to enhance resin-Zirconia bonding. Plasma or gas-fluorination effectively improved the ceramic-Zirconia bond strength, probably because it increased hydroxylation on the surface to allow for covalent bonding between Zirconia surface and resin cement (Piascik *et al*., 2011a; 2011b; 2012). Acidic treated with Piranha solution also created hydroxylation at Zirconia surface, which strongly increased the bond strength between zircon and resin cements, such as Multilink (Ivoclar Vivadent). However, it didn't improve MDP-containing resin cement, Panavia F2.0 (Kuraray) (Lohbauer *et al*., 2008). The laser treatments, such as erbium: yttrium-aluminum-garnet (Er: YAG) Er: YAG and neodymium:: yttrium-aluminum-garnet (Nd: YAG) laser, significantly increased the bond strength of Zirconia, while CO (2) laser treatment was less effective for improving Zirconia bonding (Akin *et al*., 2011; 2012;

Paranhos *et al*., 2011). However, it was reported that the laser treatment, such as Er: YAG laser, did not result in a durable resin/Zirconia bond. The microshear bond strength was dropped significantly after 6 months water storage (Foxton *et al*., 2011). Selective Infiltration Etching (SIE) method used principles of heat-induced maturation and grain boundary diffusion to transform nonretentive Zirconia surfaces into a highly retentive surface, resulting in improved Zirconia-resin bond strengths (Aboushelib *et al*., 2007; 2008; 2009; 2010; Casucci *et al*., 2011; Mirmohammadi *et al*., 2010a). Nano-alumina coating, a non-invasive method, has been developed for Zirconia surface treatment. Hydrolysis of alumina nitride powder on Zirconia surface created a nano-alumina coating (240 nm thick) and a highly retentive Zirconia surface, significantly improving resin-Zirconia bond strength (Jevnikar *et al*., 2010). However, surface roughness of Zirconia without a following application of phosphate-based primer, might not be able to provide durable Zirconia-resin bond strength (Aboushelib *et al*., 2009).

Saliva contamination significantly affected resin bonds to Zirconia ceramic and its durability. After saliva contamination, X-ray Photoelectron Spectroscopy (XPS) revealed an organic coating on Zirconia. Cleaning with water rinsing, with isopropanol, or with phosphoric acid was not able to remove the contamination. Airborne-particle abrasion was the most effective cleaning method (Yang *et al*., 2008). On nano-alumina coated Zirconia surface, phosphoric acid cleaning was effective in removal of saliva contamination, but was not effective in the removal of the silicone disclosing agent (Zhang and Degrange, 2010). It was also reported that air abrasion at 0.05 MPa and ultrasonic cleaning were able to improve resin-Zirconia bond strength and its durability (Attia and Kern, 2011b).

Primers:
Silica-based ceramics: Silane coupling agents or silanes in dentistry are organic compounds that contain polymerizable groups, such as (meth)acrylates, in one end and silane alkoxy groups in the other. The (meth) acrylate functional groups can polymerize with an organic matrix of dental resin materials (e.g., dental resin cements, composites, adhesives). The silane alkoxy group can react with a hydroxylated surface, like silica-based porcelain and ceramic *via* a chemical covalent bond Si-O-Si (Thompson *et al*., 2011; Blatz *et al*., 2003). Silane treatment after HF-etching remains the most effective method for improving resin bonding with silica-based ceramics (Panah *et al*., 2008; Nagai *et al*., 2005). Studies showed that phosphate-based

primers (e.g., Metal/Zirconia Primer, Ivoclar Vivadent; Alloy Primer, Kuraray) which contained no silane were not effective to improve resin bond strength (bond strength was 0 on polished ceramic surface) on silica-based felds pathic ceramics. The primers containing only silane monomer was the most effective for improving resin bonding to silica-based ceramics (Queiroz *et al*., 2012). However, the primers which contained silane and other monomers (such as Clearfil Ceramic Primer which contained a silane and phosphate monomer), was not effective (bond strength was 0 on polished ceramics). It was probably because the extra resin monomer inhibited the condensation reaction between silanes and silica (Chen *et al*., 2011b).

Non-silica-based Zirconia ceramics: Silanes are commonly used for coupling with silica-based ceramics *via* the formation of chemical covalent bond (Si-O-Si), to achieve a chemical bonding between resin and ceramics. Zirconia ceramics have silica-free surface and possess relatively non-polar surface. It is more chemically stable than silica-based ceramics, so traditional silane chemistry is not usually effective for Zirconia (Thompson *et al*., 2011). In recent years, silica-coating techniques have been explored to convert silica-free into silica-rich zirconia surface, for utilizing the chemical bonding provided by silanation. Tribochemical silica coating (e.g., Rocatec or CoJet system, 3M ESPE) is a commonly used and commercial technique, which air-abrades Zirconia surface with alumina particles that have been coated with nano-silica, resulting the impregnation of nano-silica into the Zirconia surface. Studies showed tribochemical silica-coating followed by silanation significantly enhanced bond strengths between zirconia and resin materials (Xible *et al*., 2006; Ozcan *et al*., 2011; Passos *et al*., 2010), but it was not clear whether it was caused by silica-coating or the surface roughening effect of air-abrasion. After silica-coating, different silence might have different effects on resin-Zirconia bond strengths. Silanation with the combination of functional (3-acryloxypropyl)trimethoxysilane with cross-linking bis[3-(trimethoxysilyl)propyl]amine or glycidoxypropyltrimethoxysilane seemed to have higher bond strengths than other silanes (Lung *et al*., 2012; Matinlinna and Lassila, 2011)

Tribochemical silica-coating followed by a silane coupling agent application was originally designed for surface treatment of soft materials like metals. It is a clinically proved method to enhance the bonding of resin materials to dental metal materials (Matinlinna and Vallittu, 2007). However, Zirconia ceramics are densely sintered mechanically tough materials, which

might be difficult to be coated by silica. Research studies showed that the tribochemical silica-coating/silanation had the same or similar effects as regular air-abrasion with alumina particles on improving zirconia-resin bond strengths, indicating tribochemical silica-coating provided only air-abrasion effect for creating surface roughness (Akyil *et al*., 2010; Re *et al*., 2008; Tanaka *et al*., 2008; Smith *et al*., 2011). It was reported that tribochemical silica-coating didn't provide stable resin-Zirconia bond strength (Kern and Wegner, 1998). The reason was probably that silica was not strongly attached to Zirconia surface. The EDXS analysis and SEM studies showed that the coating silica on Zirconia surface could be cleaned away by ultrasonication in water or pressurized water spray (Nishigawa *et al*., 2008; Chen *et al*., 2011a), indicating that no stable chemical bond was formed between silica and zirconia. The silica was probably deposited on the Zirconia surface *via* weak physical force, such as van-der-Waals forces, which might not be strong and stable enough in a clinical situation. Further investigation into this technique would be necessary before a clinical recommendation is given.

Several other silica-coating techniques have been developed for Zirconia surface treatment in recent years. Pyrochemical modification modified Zirconia surface by utilizing flame treatment with tetraethoxy silane containing butane as fuel gas (Janda *et al*., 2003). In this process, six fragments were deposited onto the Zirconia surface via weak physical force (van-der-Waals forces), resulting in weak bonding. Another method used the glazing techniques by applying thin coatings of acid-etchable glasses/porcelain on zirconia, followed by HF-etching and silane treatment. This technique resulted in a significantly enhanced resin-Zirconia bond strengths (Everson *et al*., 2012; Valentino *et al*., 2012; Fushiki *et al*., 2011; Ntala *et al*., 2010). The internal coating technique (INT) (Kitayama *et al*., 2009; 2010a) followed by silanation also improved Zirconia-resin bond strengths. Other silica-coating methods include gas-phase chloro-silane pretreatment (Piascik *et al*., 2009) and sol-gel process silica-coating (Zhang *et al*., 2009). Further investigations into these techniques are required before clinical recommendations.

In the past 5 years, bonding agents/primers (both commercial and experimental products) containing organo-phosphate monomers, such as 10-Methacryloxydecyl Dihydrogen Phosphate (MDP), have been developed for improving bond strengths of resin materials to silica-free Zirconia surface (Tanaka *et al*., 2008; Magne *et al*., 2010). Studies have shown the commercial phosphate-monomer-containing-zirconia

primers, such as Metal/Zirconia Primer (Ivoclar Vivadent), Monobond Plus (Ivoclar Vivadent), Clerafil Ceramic Primer (Kuraray), Signum Zirconia Bond (Heraeus), AZ Primer (Shofu) and ZPrime Plus (Bisco) significantly improved the initial and long-term resin bond strengths to zirconia ceramics (Cura *et al*., 2011; Azimian *et al*., 2011; Koizumi *et al*., 2012; Attia and Kern, 2011a; Ural *et al*., 2010; Takeuchi *et al*., 2010; Kitayama *et al*., 2010b; Lehmann and Kern, 2009; Magne *et al*., 2010). The metal primes that contain phosphate monomers, such as Alloy Primer (Kuraray), Estenia Opaque Primer (Kuraray) were also effective for improving bond strengths between zirconia and resin cements (Souza *et al*., 2011; Yun *et al*., 2010; Nakayama *et al*., 2010; Lehmann and Kern, 2009). Some newly designed experimental bonding agents which contained phosphate monomers, such as 6-methacryloyloxyhexyl phosphonoacetate (6-MHPA), also showed strong adhesion to Zirconia ceramic materials (Ikemura *et al*., 2011a; 2011b; 2011c). It was reported that the surface treatment of a combination of air-abrasion and phosphate-monomer-containing primers improved the durability of Zirconia-resin bond strengths (Lindgren *et al*., 2008; Kern *et al*., 2009; Akgungor *et al*., 2008). Other studies showed the combination of an organophosphate monomer (e.g., MDP) with another functional monomer further improved Zirconia-resin bond strengths. For instance, ZPrime Plus which contains both organophosphate monomer and carboxylate monomer, had higher bond strength than other commercial Zirconia primers (Magne *et al*., 2010; Chen *et al*., 2011a; 2012; Piascik *et al*., 2012). The primers contain both MDP and a zirconate coupler, or contain both MDP and VBATDT (6-N-4-vinylbenzylpropylamino-1,3,5-triazine 2,4-dithione) showed higher bond strengths than MDP alone (Yoshida *et al*., 2006; Souza *et al*., 2010).

The chemical structure of organo-phosphate monomer contains polymerizable functional groups and phosphoric acid (phosphate) groups. The polymerizable groups, such as (meth) acrylates, can copolymerize with the matrix of (meth) acrylate-based dental resin cements, composites and adhesives (e.g. BisGMA-based materials). The phosphoric acid groups have a strong adhesion to Zirconia ceramics. In recent years, the chemical bond formation (*via* Zr-O-P covalent bond) between phosphate monomers and Zirconia ceramics has been postulated (Yoshida *et al*., 2006). Studies with X-ray and NMR MAS ^{31}P confirmed that a stable chemical bond (Zr-O-P) between organophosphate (Octyl phosphate) and Zirconia was formed (Carriere *et al*., 2004). Later, it was confirmed by secondary ion mass spectrometry (SIMS) that ZPrime Plus, an MDP-

containing zirconia primer, formed a chemical bond (Zr-O-P) with zirconia ceramics (Chen *et al*., 2012). ZPrime Plus showed stable resin-zirconia bond strength (bond strength value had no decrease after 2-year aging) probably due to the chemical covalent bond (Zr-O-P) formation between zirconia and the primer (Chen *et al*. 2012).

Composite cements: After surface roughness and/or chemically priming of dental ceramics, resin based composite cements are used for luting of ceramic restorations (Blatz *et al*., 2003). Resin composite cements contain inorganic fillers and resin monomers, such as BisGMA, UDMA and TEGDMA. They have similar compositions as conventional restorative composites, but usually with a less amount of fillers and higher flowability. Traditional resin composite cements contain no adhesion functional monomer (e.g. phosphate-monomers) and require a separate ceramic primer (i.e. silane primers for silica-based ceramics and phosphate-monomer-containing primers for Zirconia) to achieve a strong adhesion between resin cements and ceramics. The film thickness of a resin cement might significantly affect the short-term and long-term bond strengths. It was reported that greater resin cement film thickness (100 μm vs. 50 μm) resulted in lower bond strength of resin materials to lithium disilicate ceramics (Cekic-Nagas *et al*., 2010). Another study showed the Zirconia bond strengths were significantly reduced when the resin cement layer was thick (Egilmez *et al*., 2012). Contrary to the research result, Lee *et al*. (2011) found that differences in cement thickness (40 or 160 μm) did not influence the resin-Zirconia bond strength given the same cements and storage conditions.

In recent years, phosphate-monomer containing self-adhesive resin cements have been developed and commercialized. Examples of self-adhesive cements include BisCem (Bisco), G-Cem (GC), Clearfil SA Cement (Kuraray), RelyX Unicem (3M ESPE) and MaxCem (Kerr). Phosphate-monomers were effective agents for improving Zirconia bonding, but not effective for improving resin bonding to silica-based ceramics. It was reported that traditional resin cements had a better bonding efficacy and more durable bond strength than self-adhesive resin cements to the lithium disilicate glass ceramics (Hooshmand *et al*., 2012; Luhrs *et al*., 2010; Kumbuloglu *et al*., 2005), probably because self-adhesive cements had weaker physical properties than conventional resin cements. Due to the phosphate monomers they contain, self-adhesive cements or phosphate-monomer-containing resin cements usually had mild bond strengths to Zirconia ceramics even without a separate primer treatment

(Yang *et al.*, 2010; Luthy *et al.*, 2006; Blatz *et al.*, 2010; Osorio *et al.*, 2012; Miragaya *et al.*, 2011; Mirmohammadi *et al.*, 2010b; Nakamura *et al.*, 2010). However, the bond strengths of self-adhesive cements were usually weak, compared to traditional resin cements with Zirconia primers (Nothdurft *et al.*, 2009; Zhang *et al.*, 2010a). The bond strength of self-adhesive cements on Zirconia could be improved by application of phosphate-monomer-containing primers (Zhang *et al.*, 2010b; Cavalcanti *et al.*, 2009). Compared to traditional resin cements, self-adhesive resin cements usually have weaker physical properties, are more hydrophilic, have higher water sorption and tends to faster hydrolytic degradation. Research showed phosphate-monomer containing Panavia F2.0 (Kuraray) had no adhesion (0 MPa) on the Zirconia after 6,000 thermal cyclings (Ozcan *et al.*, 2008). The bond strength of self-adhesive cement RelyX UniCem (3M ESPE) was significantly affected by thermocycling aging, while the bond strength of traditional resin cements did not significantly change after aging (D'Amario *et al.*, 2010). Another problem of self-adhesive resin cements are that they usually had poor self-cure ability (10.8-24.9% degree of conversion in self-cure mode) (Vrochari *et al.*, 2009). In the situation of opaque ceramics such as lithium disilicates or Zirconia ceramics, self-curing plays a critical role in clinical restorations. Vrochari *et al.* (2009) stated that "The low %DC found raises questions as to whether these materials can be successfully used in clinical applications".

Resin modified glass ionomer cement, a restorative material based on the reaction of silicate glass powder and polyalkenoic acid, is occasionally used for Zirconia cementations. However, due to its weak physical properties and lack of phosphate-monomer, it had an even poorer bond strength than a self-adhesive cement to Zirconia (Peutzfeldt *et al.*, 2011; Kim *et al.*, 2011; Attia, 2011). The (resin-modified) glass ionomer cements, such as Fuji I and Ketac Cem yielded near-zero or zero bond strength values (lower than self-adhesive cement Panavia 2.0) on Zirconia after thermocycling. All debonded specimens showed adhesive failure (Kim *et al.*, 2011). Another study also showed resin-reinforced glass-ionomer cement, such as RelyX Luting (3M ESPE) and Fuji Plus, could not offer a stable bond to air-abraded Zirconia ceramic after thermocycling (60-70% bond strength decrease after 20000 times of thermocycling) (Zhang *et al.*, 2010a). It was reported that zinc phosphate cement had an even lower bond strength of Zirconia than resin modified glass ionomer cements (Uo *et al.*, 2006).

CONCLUSION

The resin bond to silica-based ceramics, like lithium disilicates, is well documented. Preferred bonding methods are hydrofluoric acid-etching and subsequent silane treatments. The preferred protocol for resin bond to Zirconia is the combination of surface roughness and treatment with a phosphate-containing Zirconia primer followed by cementation with hydrophobic non-phosphate-containing resin cement.

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