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# EFFECT OF SURFACE CONDITIONING METHODS ON BOND STRENGTH OF RESIN CEMENT TO ZIRICONIA-REINFORCED CERAMIC

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## *ABSTRACT*

*This study was conducted with the objective of evaluating the effect of three surface conditioning methods on bond strength of resin cement to zirconia reinforced ceramic. The literature was electronically searched in PUBMED, MEDLINE, EMBASE, and SCOPUS to select relevant articles that evaluated the bond strength between zirconia and composite cements. A manual search was performed by scanning the reference lists of included studies. All articles were published online before March 2020, and in English. From electronic database and manual searches, the key word phrases used were zirconia and its bonding with resin cements 439 and surface treatment of zirconia 385 studies were identified 385. N articles with test results met the inclusion criteria and were selected on the resin bond to silica-based ceramics, on the bond to aluminum-oxide ceramics, and 3 on the bond to zirconium-oxide ceramics. Additional references were included to accompany statements of facts. Comparison of the bond strength of the three groups (I, II, III) by one-way ANOVA was done. It was seen that there was a statistically significant difference within the groups ($P<0.05$) with Group II, that is laboratory silica coating showing the highest mean bond strength (28.23 $\pm$ 1.53 MPa), followed by Group I that is laboratory grit blasting (20.2 $\pm$ 2.33 MPa). Group III that is hydrofluoric acid-etching showed the least mean bond strength (10.41 $\pm$1.46 MPa).The effect of three surface conditioning methods on the micro tensile bond strength of resin cement to a glass infiltrated zirconia reinforced alumina-based core ceramic was variable. Roughening the ceramic surfaces with air particle abrasion with 110µm $Al_2O_3$ followed by coating of silica particle with size of 110 µm $SiO_2$ and silanization prior to cementation provided higher bond strength when compared with air particle abrasion with 110µm $Al_2O_3$ and salinization. Hydrofluoric acid gel used for conditioning the reinforced ceramics showed the least mean shear bond strength.*

***KEYWORDS:*** *Zirconia; Surface Conditioning, Shear Bond Strength*

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## INTRODUCTION

The increased demand for esthetic restorative treatment in dentistry has made dental ceramics an often-used material for both anterior and posterior restorations[1]. Restoring partially destructed teeth using indirect ceramic restorations such as inlays, on lays and laminate veneers has been encouraged by the development of adhesive materials and techniques.

Adhesive techniques allow the brittle and "fragile" ceramic to become a reliable tooth restoration system with an adequate stress distribution to the underlying tooth structure [2, 3]. Chemical etching selectively dissolves the glassy matrix and crystals in ceramics to generate irregular surface topography of micro retentive channels [2.] Among the commonly used etchants, hydrofluoric acid seems most effective in creating distinct morphologic changes of deep channels and grooves associated with the increase of bond strength with a composite. Ceramics with high crystalline content (aluminum and zirconia oxides) are reported to present more favorable clinical results than feldspathic, leucite, and lithium disilicate ceramics[4]. The increased content of alumina (Al2O3) in feldspathic ceramics led to a significant increase in mechanical properties of these materials, allowing indication for more predictable metal free restorations in regions where high mechanical strength is needed. Zirconium oxide all-ceramic materials have attractive properties, such as high strength [4,5] and biocompatibility[6,7,8] that permit their use as core materials for all-ceramic crowns [9] and fixed partial dentures (FPDs) [5]. These favorable mechanical properties are due to phase transformation toughening, which increases crack propagation resistance. Zirconia, a high strength ceramic has been recently introduced as a core material for complete coverage crowns and bridges [6]. An increasing number of all ceramic materials and systems are currently available for clinical use[9]. Chemical etching selectively dissolves the glassy matrix and crystals in ceramics to generate micro retentive channels[2]. Already discussed the commonly used etchants, hydrofluoric acid seems most effective in creating distinct morphologic changes of deep channels and grooves associated with the increase of bond strength with a composite[10]. Multiple clinical studies document excellent long-term success of resin bonded restorations, such as porcelain laminate veneers, ceramic inlays and onlays, resin-bonded fixed partial dentures, and all-ceramic crowns. A strong, durable resin bond provides high retention improves marginal adaptation and prevents micro leakage and increases fracture resistance of the restored tooth and the restoration. Adhesive bonding techniques and modern all-ceramic systems offer a wide range of highly esthetic treatment options. Bonding of ceramic to dental tissue is based on the adhesion of luting cement to the ceramic substrate, together with the adhesion of luting cement to enamel and / or dentin[9]. Zirconia restorations can be cemented by conventional methods but use of resin-luting agent enhances retention and provides better marginal seal[6]. Establishing a strong and stable bond of Zirconia with resin-luting agent has always proven to be difficult as the material is acid resistant and does not respond to common etching and silanization procedures used for other glass containing ceramics. Therefore, resin luting cements could not be used for Zirconia based restorations. With surface conditioning increased adhesion between Zirconia and resin-luting agent could be achieved. Airborne- particle abrasion using fine alumina oxides under pressure is also used to modify the ceramic surface as there is a risk of tissue damage when using hydrofluoric acid. The procedure removes relatively weaker phases to create an irregular rough surface and to increase surface area for bonding. Meanwhile, it has been suggested that a combination of airborne particle abrasion followed by etching would provide a better surface for composite-ceramic bonding because neither etching or airborne-particle abrasion alone generates enough mechanical retentive characteristics on ceramic surface for clinical longevity[11].However, there is limited knowledge as to whether micromechanical retention using large or small particle size increases resin bond to high-strength ceramics of different microstructures and chemical compositions[12]. There are very few studies on the bond strength of resin cements to the zirconium based ceramics in combination with conditioning methods. In view of this, we have taken up the study.

## OBJECTIVES

The objective of the study was to evaluate the effect of three surface conditioning methods on the bond strength of resin cement to zirconia ceramic.

## METHOD OF STUDY

The literature was electronically searched in PUBMED, MEDLINE, EMBASE, and SCOPUS to select relevant articles that evaluated the bond strength between zirconia and composite cements. A manual search was performed by scanning the reference lists of included studies. All articles were published online before March 2020 and in English. From electronic database and manual searches, the key word phrases used were zirconia and its bonding with resin cements 439 and surface treatment of zirconia 385 studies were identified 385. N articles with test results met the inclusion criteria and were selected on the resin bond to silica-based ceramics, on the bond to aluminum-oxide ceramics, and 3 on the bond to zirconium-oxide ceramics. Additional references were included to accompany statements of facts.

### Surface Treatment with Chemicals: Acid Etching

The most common STM for AC to ceramic restorations is based either on micromechanical bond obtained with hydrofluoric acid etching, particles sandblasting or on chemical bond, obtained by the application of a silane coupling agent[2.] HF removes the glassy matrix of glass ceramics creating a high surface energy substrate with micro porosities for the penetration and polymerization of resin composites, that is, enabling a micromechanical interlocking[2].However, HF etching does not produce any change in arithmetic roughness (Ra) of ZrO2 [4]The negligible effect of the HF on the ZrO2 surface occurs due to the absence of glassy matrix, resulting in low bond strength values[2, 4]. Functional monomers Special functional monomers have been used to improve the adhesion to ZrO2. These materials present a chemical affinity for metal oxides and can be included both in resin cement and adhesives or applied directly over the ceramic surface[13]. Phosphate ester monomers, such as 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP), chemically react with ZrO2, promoting a water-resistant bond to densely sintered zirconia ceramics[13.]

### Mechanical Surface Treatments

Aluminum Oxide micro abrasion Particles - Aluminum oxide particles (Al2O3) micro abrasion is an effective air abrasion method.

### Alternative Treatments

Different alternative methods to treat ZrO2 surfaces have been proposed and evaluated in order to produce a reliable adhesion, particularly in long term. A wide number of mechanical, chemical or both approaches have been tried to change the ZrO2 surface to increase the surface bond area, surface energy, or wettability

Table 1 shows a good adhesion to the dental tissues has been achieved successfully over a period. Current research efforts are also aimed at the optimization of the adhesion between composites to metals (alloys), composites to ceramics and composites to other composites.

Several surface conditioning methods have been developed over the last few decades to produce adequate adhesion to the adherent for restorations. The present study examined the effect of different surface conditioning methods by determining bond strength of a resin cement to glass infiltrated zirconia ceramics.

This research on surface conditioning of zirconia-reinforced ceramic surfaces with air particle abrasion and applying silane preceding to cementation providing high bond strengths and silica coating followed by silanization evidently improved the bond among the luting cement and the ceramic surfaces. The silica particles attached on the surface of ceramic by silica coating allows the surface to provide a basis for silane to react. Silane acts as a coupling agent in the ceramic resin bond, which adsorbs onto and alters the surface of the ceramic, thereby facilitating chemical interaction[12]. If alumina or zirconia ceramics are glass infiltrated, they are melted together at high temperatures to form a ceramic composite. The chemical components of the ceramics (traces such as $Li_2O$, $Na_2O$, $K_2O$, CaO, MgO) are then bonded to each other by strong covalent bonds with hydroxyl groups at the surface of the ceramic material [13]. Oyagüe et al. noted a statistically significant decline in bond strength of MDP containing resin cement after 6 months of water storage when luting to either untreated or sandblasted zirconia surfaces; in contrast, no significant bond strength variability was seen for this type of resin cement after 6 months of water exposure when luting to silica-coated zirconia surfaces [14]. Once the surface is air abraded, this would produce more hydroxyl groups on the surface and augment the micro-mechanical retention. Moreover, the methoxy groups of silanes would react with water to form silanol groups that in turn, will react with the surface hydroxyl groups to form siloxane network. Amphoteric alumina in the ceramic matrix may perhaps form chemical adhesion, covalent bridges, through its surface hydroxyl groups with hydrolyzed silanol groups of the silane: –Al–O–Si[6]. The In-Ceram ceramic system tested in this study, InCeram Zirconia (INC-ZR), is glass infiltrated. However, the glass infiltration facilitated better silane bonding and improved strength values were obtained for this ceramic. The findings are in compliance with the study done by Ozcan and Vallittu[6], though the experimental set was different, bis-GMA based resin cement was used and shear bond tests were performed. Selection of material and clinical recommendations for resin bonding are based on mechanical laboratory tests that show great variability in materials and methods. The test that is usually performed is the shear bond test. However, the specific fracture pattern in shear testing may cause cohesive failure in the substrate that may lead to erroneous interpretation of the data while in micro tensile tests; stress distribution was reported to be more homogeneous[9, 15-17]. And, for this reason, micro tensile test was employed in this study, similar ceramic-cement performance was observed in dry conditions in the study of Ozcan and Vallittu[6].The results of this study indicated that sandblasting with 110µm $Al_2O_3$ followed by silica coating with particle size of 110 µm $SiO_2$ produced statistically higher mean bond strength values than with chair side grit blasting using 110µm grain sized $Al_2O_3$ particles alone. In another study by Valandro et al [18], ten blocks (5x6x8 $mm^3$) of In Ceram Zirconia and Procera ceramics were fabricated according to each manufacturer's instructions and duplicated in composites. The specimens were assigned to one of the two following treatment conditions: (1) airborne particle abrasion with 110-µm $Al_2O_3$ particles + silanization, (2) silica coating with 30µm $SiO_2$ particles (CoJet, 3M ESPE) + silanization. Each ceramic block was duplicated in composite resin. The composite blocks were bonded to the surface conditioned ceramic blocks using a resin cement system (Panavia F, Kuraray, and Okayama, Japan). One composite resin block was fabricated for each ceramic block. The bond strength tests were performed in a universal testing machine. Bond strength values were statistically analyzed using two-way ANOVA and Tukey's test ($\leq 0.05$). It was found that Silica coating with silanization increased the bond strength significantly for all three high-strength ceramics (18.5 to 31.2 MPa) compared to that of airborne particle abrasion with 110-µm $Al_2O_3$ (12.7-17.3 MPa) (ANOVA, $p < 0.05$). In our study also, we found the highest shear bond strength in Group II (Laboratory Silica Coating) followed by Group I (Laboratory Gritblasting). The differences were found to be statistically significant ($P< 0.05$). Ozcan M [9] in 2003 conducted a study where different conditioning methods were tested to promote the adhesion between some of the substrates and the resin composites. This research suggested satisfactory etching results for ceramic with glassy matrix using HF acid. After silica coating silanization was done in special furnace this was not only very effective for bonding the ceramic but in fact improved the results of core application on the titanium posts. The promising results obtained from this research for titanium alloy could help in researches on other alloys used in dentistry and can benefit from these conditioning systems. The initial step after the surface treatment test s in this research is involves silane coupling agent application. On the preconditioned surface, the application of silane coupling agent provides a hydrogen and covalent bond. The results of this study suggest recent surface conditioning techniques based of the combination of micromechanical retention and chemical coating for the durable bonding in adhesive dentistry which contrasts with what was being regularly applied for adhesion principles creating macro mechanical retention [9]. Although HF acid gel worked well in terms of receiving high bond strength on glass matrix ceramics, the results were poor when it was used for conditioning the reinforced ceramics[19-23]. Ceramics or composites etching with HF acid are a commonly employed option since it can be easily applied at the chair side without any requirement of additional devices. However, this technique has major drawbacks as it may lead to serious clinical problems. HF acid gel together with HCl (hydrochloric acid, a very strong acid) fits to the group of hydrogen halogens. They are corrosive, hazardous and cytotoxic acids. If HF vapors are inhaled, they can cause lung edema and after weeks, liver and kidney insufficiency can appear [24]. When compared to the above study, our study too showed similar findings. Group III i.e. Hydrofluoric acid etching showed the least mean shear bond strength between the groups which was statistically significant ($P< 0.05$). Qeblawi DM, Muñoz CA et al conducted a study [25] to assess the result of surface treatment of yttria-partially stabilized zirconia on its flexural strength and the effect of mechanical and chemical surface treatments on its bond strength to a resin cement, zirconia bars of (4 x 5 x 40 mm) were prepared from zirconia blocks for flexural strength evaluation. Finished using a diamond rotary cutting instrument, sintered, then assigned into 4 groups: (1) control (no treatment), (2) airborne-particle abrasion, (3) silicoating, and (4) wet hand grinding. Mechanical treatment included: (1) control (no treatment), (2) airborne-particle abrasion, (3) silicoating, or (4) wet hand grinding. Chemical treatment comprised: (1) control (no treatment), (2) acid etching followed by silanation, (3) silanation only, or (4) application of zirconia primer. Zirconia blocks were bonded to dentin using resin cement (Multilink Automix), then light polymerized. After storage, the specimens were loaded to failure with the notched shear bond test method in a universal loading apparatus. It was seen that airborne-particle abrasion and hand grinding significantly increased flexural strength. The highest shear bond strength values were achieved for the following groups: silicoated + silanated > hand ground + zirconia primer > airborne-particle abraded + silanated >zirconia primer > airborne-particle abraded + zirconia primer. It was concluded that mechanical modification of the surface increased the flexural strength of Y-TZP. In our study also we found the mean bond strengths in the following order: silicoated + silanated >airborne particle abraded + silanated. In another study by Yun JY [26] on effect of sandblasting and various metal primers on the shear bond strength of resin cement to Y-TZP ceramic found out that the bond strength of the specimens treated with sandblasting and metal primer (Alloy primer) was significantly higher than those of the other subgroups. Chemical modification by acid etching followed by silane coating had the least bond strength. From the results of our study, clinical implications that could be derived are: Comparatively recent surface conditioning techniques based on the combination of micromechanical and chemical conditioning should be considered for better-quality adhesion of resin cements to glass-infiltrated zirconia ceramics. Nevertheless, the results of this study together with some other studies reveal good adhesion of silica particles in the vitreous phases of the glass-infiltrated zirconia ceramics[27-30]. Some previous studies reported high and stable bond strength to the zirconia reinforced ceramic after airborne particle abrasion using Al2O3 particles in combination with phosphate monomer based resin cement [1,4,31]. Equating the results of these studies with this present study, it can be suggested that the silica coating and silanization may allow a better bond strength to the zirconium with this resin cements. The general consequence of this research advises that comparatively recent surface conditioning techniques based on the combination of micromechanical and chemical conditioning should be considered for improved adhesion of resin cements to glass-infiltrated zirconia ceramics. More significantly, these methods seem to offset the position of the variety of substrates and thus could be suitable to apply on a wide range of high-strength ceramics [32]. Earlier these equipment's were considered sophisticated and expensive, but they are recently simplified and brought to the chair side. The limitation of the study was that it is an in-vitro study. Although all possible efforts have been made to best simulate clinical situations, at best an in-vitro study can be used to rank performance and give an indication of likely clinical performance. By employing chair side devices for airborne particle abrasion, the issue of contamination during transportation of the restoration from the laboratory to chair side could also be avoided. As long as the available conditioning methods will not be optimized, the development in the high-strength ceramic field is expected to continue experiencing failures.

## RESULTS AND DISCUSSIONS

**Table 1: Pico (Problem, Intervention, Comparison, Outcome)**

| Author & Year | Problem | Intervention | Comparison | Outcome |
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| Kern M, Thompson VP[2]. 1994 | Effects of sandblasting and coating techniques on volume loss, surface morphology, and surface composition of In-Ceram ceramic | Sandblasting and coating techniques on volume loss, surface morphology, and surface composition of In-Ceram ceramic. Tribochemical coating with the Rocatec system was used. | Sandblasting of In-Ceram ceramic compared with a feldspathic glass ceramic (IPS-Empress), | Volume loss through sandblasting was 36 times less for In-Ceram ceramic compared with a feldspathic glass ceramic (IPS-Empress), and sandblasting of In-Ceram ceramic Sandblasting of all ceramic clinical restorations with feldspathic glass materials should be avoided, but for In-Ceram ceramic the volume loss was within an acceptable range and similar to that of noble metals did not change its surface composition. After tribochemical coating with the Rocatec system, a layer of small silica particles remained that elevated the silica content to 19.7 weight percentage (energy dispersive spectroscopy). Ultrasonic cleaning removed loose silica particles from the surface and decreased the silica content to 15.8 weight percentage, which suggested firm attachment of most of the silica layer to the surface. |
| Aida M, Hayakawa T, Mizukawa K[3]. 1995 | To evaluate the adhesion of composite resin to five different surface conditions of porcelain samples that were treated | To evaluate the adhesion of composite resin to five different surface conditions of porcelain samples those were treated with three kinds of silane agents. Two of these were commercially available Porcelain Liner M and Tokuso Ceramic Primer, and one was an experimental agent. One component of these commercially available silane agents was meth-acryl-oxypropyl tri-meth-oxy silane, and the other was the | Two of these were commercially available Porcelain Liner M and Tokuso Ceramic Primer, and one was an | As a result of the effective formation of siloxane bonds by mixing with acid solution, porcelain surface conditions did not affect the bond strengths significantly. |

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| | with three kinds of silane agents | carboxylic acid. | experimental agent. | |
| Özcan M, Alkumru HN, Gemalmaz D[5]. 2001 | Shear bond strength of different luting cements | evaluate the effect of three different surface treatments on the bond strength of four different luting cements | (1)etching for 90 seconds with 5% hydrofluoric acid gel, (2)sandblasting (110-µmAl2O3), (3)tribochemical silica coating | Shear bond strength of compomer cement following tribochemical silica coating was significantly lower in comparison to resin cement with better outcome. |
| Ernst CP et al [10]2005 | To determine the retentive strength of 4 resin-cement systems, a compomer, a glass ionomer cement, a resin-modified glass ionomer cement, and a self-adhesive resin for luting zirconium oxide ceramic crowns | One hundred twenty extracted human teeth were randomly divided into 12 groups (n = 10) and prepared in a standardized manner (5 degree taper, 3 mm occluso-gingival height). All-ceramic crowns (Lava) were fabricated in a standardized manner for each tooth. The following cements and corresponding bonding regimens were used to lute the crowns to the teeth according to manufacturers' recommendations: CO, Compolute / EBS Multi; CO / RT, Compolute / EBS Multi / Rocatec; CB, Superbond C & B; CB / RT, Superbond C&B / Rocatec; CB / PL, Superbond C & B / Porcelain Liner M; PA, Panavia F; DC, Dyract Cem Plus / Xeno III; CH / PL, Chemiace II/Porcelain Liner M; RL, RelyX Luting, K / C, Ketac Cem / Ketac Conditioner; K, Ketac Cem; and RU, RelyX Unicem. After thermal cycling (5000 cycles, 5 0 C-550 C), the outer surfaces of the cemented zirconium oxide ceramic crowns were treated (Rocatec) to improve bonding and then placed into a low-shrinkage epoxy resin block (Paladur). The block/crown and tooth components for each specimen were connected to opposing ends of a universal testing machine so that crown retention could be measured. Crowns were removed from teeth along their path of insertion. | Retentive strength of 4 resin-cement systems, a compomer, a glass ionomer cement, a resin-modified glass ionomer cement, and a self-adhesive resin for luting zirconium oxide ceramic crowns. | It was found out within the conditions of this study, that compomer-cement, the resin-modified glass-ionomer cement, and the self-adhesive resin luting agent had the same level of retentive quality as the resin luting agents, Superbond C&B, and Panavia. Rocatec pre-treatment of the ceramic surface did not improve the retentive strengths of Compolute and Superbond C&B. |
| Atsu SS, et al[11] 2006 | The effects of airborne-particle abrasion, silanization, tribochemical silica coating, and a combination of bonding/silane coupling agent | Sixty square-shaped (5x5x1.5 mm) zirconium-oxide ceramic (Cercon) specimens and composite resin (Z-250) cylinders (3x3x3 mm) were prepared. The ceramic surfaces were airborne-particle abraded with 125-µm aluminium-oxide (Al2O3) particles and then divided into 6 groups (n=10) that were subsequently treated as follows: Group C, no treatment (control); Group SIL, silanized with a silane coupling agent (Clearfil Porcelain Bond Activator); Group BSIL, application of the adhesive 10- methacryloyloxydecyl dihydrogen phosphate monomer (MDP)– | Compare the effects of airborne-particle abrasion, silanization, tribochemical silica coating, and a combination of bonding/silane coupling agent surface | The bond strength was significantly higher in Group SCBSIL than in Groups C, SIL, and BSIL (P<.001), but did not differ significantly from those in Groups SC and SCSIL. Failure modes were primarily adhesive at the interface between zirconium and the resin luting agent in Groups C and SIL, and primarily mixed and cohesive in |

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| | surface treatment methods on the bond strength of zirconiumoxide ceramic to a resin luting agent. | containing bonding/silane coupling agent mixture (Clearfil Liner Bond 2V/ Porcelain Bond Activator); Group SC, silica coating using 30µm $Al_2O_3$ particles modified by silica (CoJet System); Group SCSIL, silica coating and silanization (CoJet System); and Group SCBSIL, silica coating and application of an MDP– containing bonding/silane coupling agent mixture (Clearfil Liner Bond 2V/Porcelain Bond Activator). The composite resin cylinders were bonded to the treated ceramic surfaces using an adhesive phosphate monomer–containing resin luting agent (Panavia F). After the specimens were stored in distilled water at 370 C for 24 hours, their shear bonding strength was tested using a universal testing machine at a crosshead speed of 0.5 mm/min. Debonded specimen surfaces were examined with a stereomicroscope to assess the mode of failure, and the treated surfaces were observed by scanning electron microscopy. Bond strength data were analysed. | treatment methods on the bond strength of zirconiumoxide ceramic to resin luting agent. | Groups SC, SCSIL, and SCBSIL. It was found out that tribochemical silica coating (CoJet System) and the application of an MDP–containing bonding/ silane coupling agent mixture increased the shear bond strength between zirconium-oxide ceramic and resin luting agent (Panavia F). |
| Amaral R et al[12] 2006 | Microtensile bond strength of resin cement to a glass infiltrated zirconia reinforced alumina based core ceramics | Thirty blocks (5x5x4 mm) of In-Ceram Zirconia ceramics (In-Ceram Zirconia-INC-ZR, VITA) were fabricated according to the manufacturer's instructions and duplicated in resin composite. The specimens were polished and assigned to one of the following three treatment conditions (n=10). (1) Airborne particle abrasion with 110µm $Al_2O_3$ particles + silanization, (2) Silica coating with 110µm $SiO_2$ particles (Rocatec Pre and Plus, 3M ESPE) + silanization, (3) Silica coating with 30µm $SiO_2$ particles (CoJet, 3M ESPE) + silanization. The ceramic-composite blocks were cemented with the resin cement (Panavia F) and stored at 370 C in distilled water for 7 days prior to bond tests. The blocks were cut under coolant water to produce bar specimens with a bonding area of approximately 0.6 mm2. The bond strength tests were performed in a universal testing machine. | Comparison of three surface conditioning methods on the microtensile bond strength of resin cement to a glass infiltrated zirconia reinforced alumina based core ceramics | It was concluded from this study that Conditioning the INC-ZR ceramic surfaces with silica coating and silanization using either chairside or laboratory devices provided higher bond strengths of the resin cement than with airborne particle abrasion using 110 µm $Al_2O_3$. |
| Valandro LF[18]2006 | To evaluate the effect of two surface conditioning methods on the microtensile bond strength of a resin cement to three high-strength core | Ten blocks (5 x Review of Literature 13 6 x 8 mm) of In-Ceram Alumina (AL), In-Ceram Zirconia (ZR), and Procera (PR) ceramics were fabricated according to each manufacturer's instructions and duplicated in composite. The specimens were assigned to one of the two following treatment conditions: (1) airborne particle abrasion with 110-µm $Al_2O_3$ particles + silanization, (2) silica coating with 30 µm $SiO_2$ particles (CoJet, 3M ESPE) + silanization. Each ceramic block was duplicated in composite resin (W3D-Master, Wilcos, Petropolis, RJ, | Comparison of two surface conditioning methods on the microtensile bond strength of a resin cement to three high-strength core ceramics: | It was found that Silica coating with silanization increased the bond strength significantly for all three high strength ceramics (18.5 to 31.2 MPa) compared to that of airborne particle abrasion with 110µm $Al_2O_3$ (12.7-17.3 MPa) (ANOVA, $p < 0.05$). PR exhibited the lowest bond strengths after both $Al_2O_3$ and silica |

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| | ceramics: high alumina-based (In-Ceram Alumina, Procera AllCeram) and zirconia-reinforced alumina-based (In-Ceram Zirconia) ceramics. | Brazil) using a mold made out of silicon impression material. Composite resin layers were incrementally condensed into the mold to fill up the mold and each layer was light polymerized for 40 s. The composite blocks were bonded to the surface-conditioned ceramic blocks using a resin cement system (Panavia F, Kuraray, Okayama, Japan). One composite resin block was fabricated for each ceramic block. The ceramic-composite was stored at 37°C in distilled water for 7 days prior to bond tests. The blocks were cut under water cooling to produce bar specimens (n = 30) with a bonding area of approximately 0.6 mm2. The bond strength tests were performed in a universal testing machine (crosshead speed: 1 mm/min). | high alumina-based (In-Ceram Alumina, Procera AllCeram) and zirconia-reinforced alumina-based (In-Ceram Zirconia) ceramics. | coating (12.7 and 18.5 MPa, respectively). |
| Valandro LF[19]2007. | The microtensile bond strength of resin bonded cement (Panavia F) to silica coated, silanized, glass infiltrated highalumina zirconia (In-Ceram) ceramic in dry conditions and various aging regimens. | The specimens were placed in 1 of 4 groups: Group 1: dry conditions (immediate testing without aging); Group 2: water storage at 370 C for 150 days; Group 3: 150 days of water storage followed by thermocycling (X 12,000, 50 C to 550 C); Group 4: water storage for 300 days; Group 5: water storage for 300 days followed by thermocycling. It was found out that Group 1 showed a significantly higher microtensile bond strength value (26.2±1 MPa) than the aging regimens. Satisfactory results were seen in dry conditions, but water storage and thermocycling resulted in significantly weaker bonds between the resin cement and the zirconia. | The microtensile bond strength of resin bonded cement (Panavia F) to silica coated, silanized, glass infiltrated highalumina zirconia (In-Ceram) ceramic in dry conditions and various aging regimens. | Resulted in significantly weaker bonds between the resin cement and the zirconia. |
| Amaral R, et al[20] 2007. | To evaluate the durability of bond strength between a resin cement and aluminous ceramic submitted to various surface conditioning methods | Twenty-four blocks (5x5x4 mm3 ) of a glass-infiltrated zirconia– alumina ceramic (In- Ceram Zirconia Classic) were randomly divided into three surface treatment groups: ST1Air-abrasion with 110µm Al2O3 particles + silanization; ST2-Laboratory tribochemical silica coating method (110µm Al2O3, 110µm silica) (Rocatec) + silanization; ST3Chairside tribochemical silica coating method (30µm SiO2) (CoJet) + silanization. Each treated ceramic block was placed in its silicone mold with the treated surface exposed. The resin cement (Panavia F) was prepared and injected into the mold over the treated surface. Specimens were sectioned to achieve non-trimmed bar specimens (14 sp/block) that were randomly divided into two conditions: (a) Drymicrotensile test after sectioning; (b) Thermocycling (TC)-(6,000 xs, 5–550 C) and water storage (150 | Comparison of various surface conditioning methods for durability of bond strength between resin cement and aluminous ceramic | The majority of the failures were mixed (82%) followed by adhesive failures (18%). Gr2 presented significantly higher incidence of ADHESIVE failures (54%) than those of other groups (p = 0.0001). Both laboratory and chair side silica coating plus silanization showed durable bond strength. After aging, air abrasion with 110µm Al2O3 + silanization showed the largest decrease indicating that aging is fundamental for bond strength testing for acid-resistant zirconia ceramics in order to |

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| | | days). Thus, six experimental groups were obtained (n = 50): Gr1ST1 + dry; Gr2ST1 + TC; Gr3ST2 + dry; Gr4ST2 + TC; Gr5ST3 + dry; Gr6— ST3 + TC. After microtensile testing, the failure types were noted. ST2 (25.1 ± 11) and ST3 (24.1 ± 7.4) presented statistically higher bond strength (MPa) than that of ST1 (17.5 ± 8) regardless of aging conditions ($p < 0.0001$). While Gr2 revealed the lowest results (13.3 ± 6.4), the other groups (21.7 ± 7.4–25. 9 ± 9.1) showed statistically no significant differences. | | estimate their long-term performance in the mouth. |
| Bona AD, et al[21]2007 | To test hypothesis that silica coating (SC - Cojet, 3M-Espe) produces higher bond strength values than other ceramic surface treatments. | Specimens were fabricated and tested according to the manufacturers' instructions, and to ISO6872 and ISO11405 specifications. Sixty IZ disk specimens were polished through 1 μm and divided into 3 groups (n = 20) according to the following surface treatments: HF - 9.5 % hydrofluoric acid (Ultradent) for 1 min; SB - sandblasting with 25-μm aluminum oxide particles for 10 s; SC - silica coating for 10s. Silane (3M-Espe), adhesive (Single Bond, 3MEspe) and a composite resin cylinder (Z100, 3M-Espe) were applied and polymerized to the treated bonding area (3.5 mm in diameter). Ten specimens from each group (n = 10) were tested for σt and ten specimens were tested for σs, using a universal testing machine (EMIC DL 2000) at a crosshead speed of 1 mm/min. | Tensile (σt) and shear bond strength (σs) of a glass-infiltrated alumina-based zirconia-reinforced ceramic (IZ–Vita In-Ceram Zirconia) to a composite resin. | The groups presented the same statistical ranking of mean values for both test methods. The SC-treated IZ ceramic presented a significant increase in mean bond strength values for both test methods, confirming the study hypothesis. |
| Özcan M, Kerkdijk S, Valandro LF[22] 2008. | Evaluate the bond strength of four resin materials with various chemical composition s (2) to test their durability in dry and thermal aged conditions when they were bonded to zirconia ceramic. | Four types of resin materials namely, Panavia F 2.0, Multilink, Super Bond and Quadrant Posterior Dense, were attached to the discshaped zirconia ceramics (LAVA, 3M ESPE) using polyethylene molds and polymerized accordingly after the ceramics were wet ground finished and ultrasonically cleaned. The specimens were randomly divided into two groups for ageing conditions. While the dry groups were tested immediately after attachment of the resin cement, the other specimens were subjected to thermocycling (×6,000, 5–55°C). Bond strength results were significantly affected analysis of variance). | Bond strength of four resin materials with various chemical compositions and (2) to test their durability in dry and thermal aged conditions when they were bonded to zirconia ceramic. | Panavia F 2.0 showed the highest bond strength results under dry conditions (9.6±4.1 MPa). When manufacturers' instructions of the resin cements were followed, no adhesion (0 MPa) was achieved on the zirconia after 6,000 thermal cyclings including Panavia F 2.0. |
| Tashkandi E[23] 2009 | To evaluate the resin-composite micro-shear bond strength to zirconia using different | Fully sintered zirconia (LAVA, 3M-ESPE, Seefeld, Germany) discs were used in combination with resin composite (Filtek Supreme, 3M-ESPE, Seefeld, Germany) discs and divided into four groups of surface treatments. The micro-shear bond strength was measured by applying an axial load on the bonded interface until failure occurred. Failure load (N) was deter- mined | Resin-composite micro-shear bond strength to zirconia using different techniques of surface | It was concluded within the limitations of this in vitro study the use of an experimental primer achieved a better bond strength in combination with air-abrasion particles. |

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| | techniques of surface treatment. | and the samples were examined under a SEM and the failure type was identified. | treatment. | |
| Ozcan M, Allahbeic karaghi A, Dündar M[24] 2012. | To evaluate the effect of mechanical surface treatment of yttria-partially stabilized zirconia on its flexural strength and the effect of mechanical and chemical surface treatments on its bond strength to a resin cement. | For flexural strength evaluation, zirconia bars (4 x 5 x 40 mm) were prepared from zirconia blocks, finished using a diamond rotary cutting instrument, sintered, then assigned into 4 groups: (1) control (no treatment), (2) airborne particle abrasion, (3) silicoating, and (4) wet hand grinding. After storage for 24 hours at 37°C, flexural strength was determined using a 3-point bending test, and the results were analyzed using 1-way ANOVA ($\alpha$=.05). For shear bond strength evaluation, zirconia rods (2.5 x 3 mm) were prepared from zirconia blocks, sintered, and assigned into 16 groups. Each group underwent a combination of the following mechanical and chemical treatments. Mechanical treatment included: (1) control (no treatment), (2) airborne-particle abrasion, (3) silicoating, or (4) wet hand grinding. Chemical treatment included: (1) control (no treatment), (2) acid etching followed by silanation, (3) silanation only, or (4) application of zirconia primer. Dentin specimens were prepared from extracted molars stored in 0.5 % chloramine-T. Zirconia rods were bonded to dentin using resin cement (Multilink Automix), then light polymerized. After storage, the specimens were loaded to failure with the notched shear bond test method in a universal loading apparatus. For artificial aging analysis, the groups that achieved the highest bond strength values were duplicated, stored at 37°C and 100% humidity for 90 days, and thermal cycled before being loaded to failure. | Effect of mechanical surface treatment of yttria-partially stabilized zirconia on its flexural strength and the effect of mechanical and chemical surface treatments on its bond strength to a resin cement. | It was concluded that mechanical modification of the surface increased the flexural strength of Y-TZP. The resin bond to Y-TZP was improved by surface treatment. A combination of mechanical and chemical conditioning of the zirconia surface was essential to develop a durable resin bond to zirconia. |
| Qeblawi DM, et al[25] 2010 | Effect of sandblasting and metal primers on the shear bond strength of three commercial resin cements to Yttria-Tetragonl Zirconia Polycrystal (Y-TZP) ceramics. | One hundred and twenty Y-TZP ceramic cylinders (Ø7 mm × 12 mm) were embedded in polytetrafluoroethylene (PTFE) molds using PMMA. The specimens were divided randomly into 12 groups (n = 10), according to the surface treatments (control; sandblast- only; metal primer only; sandblast + metal primer) and metal primer-resin cements (Alloy primer – Panavia F 2.0, V-primer – Superbond C&B, Metaltite–M bond) rendered. The mixed resin cements were placed onto the treated zirconia surfaces in cylindrical shape (Ø3 mm × 3 mm) using PTFE molds. All specimens were thermocycled (5 and 55 ◦ C, 5000 cycles) and subjected to shear bond strength test by a universal testing machine with a crosshead speed of 0.5 mm/min. All data were statistically analyzed using two- | Shear bond strength of three commercial resin cements to Yttria-Tetragonl Zirconia Polycrystal (Y-TZP) ceramics. | It was concluded that Metal primers are not always effective for bonding between Y-TZP ceramics and resin cements. Even though a metal primer is not enough to be used alone, combined application with sandblasting seems to be an appropriate pretreatment for improving the bond strength of resin cement to Y-TZP ceramics, especially in Panavia F 2.0. |

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| | | way ANOVA and multiple comparison Scheffé test ( α= 0.05), and SEM images of the fractured areas were used to evaluate the fracture mode. It was seen that in Panavia F 2.0, the bond strength of the specimens treated with sandblasting and metal primer (Alloy primer) was significantly higher than those of the other subgroups. In Superbond C&B and M bond, sandblasting significantly increased the shear bond strength, but the effect of metal primers (Vprimer and Metaltite) was not significant and there was disordinal interaction. | | |
| Yun JYet al[26]2010 | To evaluate the durability of bond strength between zirconia and 3 different resin cements. | Thirty stabilized tetragonal zirconium-dioxide blocks were duplicated in dual-curing resin core buildup material specimens. Resin blocks were randomly luted to zirconium surfaces using 1) Clearfil Esthetic Cement (CLF), 2) RelyX Unicem Aplicap (RELX), or 3) Multilink Automix (MLA). After 24 h, half of the specimens from each of the 3 groups were loaded in tension until fracture (0.5 mm/min). The remaining half was tested after 6,000 thermal cycles (5 to 55°C). Data were analyzed using 2-way ANOVA and the Tukey test ($\alpha = 0.05$). Fractographic analysis was performed using a stereomicroscope. Tensile bond strength values were significantly affected by the luting agent system employed and by thermal aging ($P < 0.001$). The highest tensile bond strength values in non-thermal-aged groups were observed for specimens from the RELX and CLF groups. In contrast, in the thermal-aged groups, the highest tensile bond strength values were for the MLA and RELX groups. Moreover, while thermocycling significantly affected bond strengths in the RELX and CLF groups, the mean strength of the MLA group did not significantly change after aging. | Three different resin cements. | There was little difference in the distribution of failure modes in any group. |
| Kim HJ, Lim HP, Park YJ [34] 2011 | The effects of various surface treatments on the shear bond strength of zirconia and veneering ceramic. | Square-shaped (5 x 10 x 10 mm) zirconia (Everest) specimens were divided into 4 groups (n=8) according to surface treatment as follows: group C, grinding with #320 diamond disc (control); group A, air- borne-particle abrasion with 110 µm $Al_2O_3$; group L, application of liner (Cerabien); and group AL, airborne-particle abrasion with 110 µm $Al_2O_3$ and application of liner. A cylinder of veneering ceramic (2.4 mm in diameter and 3 mm in height) (Cerabien) was fabricated and fired on the zirconia specimens. The shear bond strength was tested using a universal testing machine. The data were analyzed statistically using a 1-way ANOVA and | Compared effects of various surface treatments on the shear bond strength of zirconia and veneering ceramic. | It was concluded that the mean in vitro shear bond strength of veneering ceramic on zirconia treated with airborne-particle abrasion was significantly higher than that subjected to liner-applied treatments. |

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| | | Tukey's multiple comparisons test (α=.05). The interface and fractured surfaces of the specimens were also evaluated by field emission scanning electron microscopy (FE-SEM). It was seen that the mean and SD values for the shear bond strength of the groups ranged from 27.87 ±3.59 MPa (for group L) to 36.63 ±2.96 MPa (for group A). The 1-way ANOVA revealed a significant difference between groups (P=.001). The airborne-particle abrasion group showed significantly higher bond strength than liner applied groups (L, AL) (P<.05). The SEM revealed that liner-applied groups (L, AL) showed primarily adhesive failure. Complete delamination and microspaces were also observed in the liner-applied groups. | | |
| Komine F, Blatz MB, Matsumura H.[35] 2011 | Current status of zirconia-based fixed restorations, including results of current in vitro studies and the clinical performance of these restorations. | They came to the conclusion that the adaptation of zirconia-based restorations fabricated with CAD / CAM technology is within an acceptable range to meet clinical requirements. In terms of fracture resistance, zirconia based fixed partial dentures (FPDs) have the potential to withstand physiological occlusal forces applied in the posterior region, and therefore provide interesting alternatives to metal-ceramic restorations. Clinical evaluations have indicated an excellent clinical survival of zirconia-based FPDs and crown restorations. However, some clinical studies have revealed a high incidence of chipping of veneered porcelain. Full coverage zirconia-based restorations with adequate retention do not require resin bonding for definitive cementation. Resin bonding, however, may be advantageous in certain clinical situations and is a necessity for bonded restorations, such as resin-bonded FPDs. | Zirconia based FPDs studies in vitro and in vivo were compared | Combined surface treatment using airborne particle abrasion and specific adhesives with a hydrophobic phosphate monomer are currently reliable for bonding to zirconia ceramics. |
| Gargava S, Ram SM [36]. 2013 | To evaluate the surface conditioning of Zirconia and its effect on bonding to resin-luting agent. | Fifteen blocks of Zirconia (VITA Zirconia) were fabricated in the laboratory according to manufacturer's instructions and embedded in acrylic resin to get 15 Zirconia samples. Fifteen composite resin cylinders were prepared one for each Zirconia sample. All the 15 Zirconia samples were divided into three groups of five samples each. Group A: Was kept as control with no surface conditioning done. Group B: Surface conditioning was done with 30µm silicon dioxide. Group C: Surface conditioning was done with 110µm aluminum oxide. Composite resin cylinders were cemented on the Zirconia samples using a resin-luting agent (Panavia F). | The surface conditioning of Zirconia and its effect on bonding to resin-luting agent. | Surface conditioning results in significant increase bond strength between Zirconia and resin-luting agent. Among the two methods surface conditioning with 30µm silicon dioxide is much better and efficient method. |
| Moradabadi A, | Bond strength | Specimens of yttrium-oxide-partially-stabilized zirconia blocks were fabricated. | Effects of two major | It was concluded that micromechanical adhesion |

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| [37]2014 | between dental resin agent and zirconia ceramic. | Seven groups of specimens with different surface treatment were prepared. 1) zirconia specimens after airborne particle abrasion (SZ), 2) zirconia specimens after etching (ZH), 3) zirconia specimens after airborne particle abrasion and simultaneous etching (HSZ), 4) zirconia specimens coated with a layer of a Fluorapatite- Leucite glaze (GZ), 5) GZ specimens with additional acid etching (HGZ), 6) zirconia specimens coated with a layer of salt glaze (SGZ) and 7) SGZ specimens after etching with 2% HCl (HSGZ). Composite cylinders were bonded to airborne-particle-abraded surfaces of ZirkonZahn specimens with Panavia F2 resin luting agent. Failure modes were examined under 30 × magnifications and the effect of surface treatments was analyzed by scanning electron microscopy (SEM) and atomic force microscopy (AFM). SZ and HSZ groups had the highest and GZ and SGZ groups had the lowest mean shear bond strengths among all groups. | mechanisms of chemical and micromechanical adhesion were evaluated on bond strength of zirconia to luting agent. | was a more effective mechanism than chemical adhesion and airborne particle abrasion significantly increased mean shear bond strengths compared with another surface treatments. |

## CONCLUSIONS

### Following Conclusions Were Made from the Study

The effect of three surface conditioning methods on the micro tensile bond strength of resin cement to a glass infiltrated zirconia reinforced alumina-based core ceramic was variable.

Roughening the ceramic surfaces with air particle abrasion with 110µm $Al_2O_3$, followed by silica coating with particle size of 110 µm $SiO_2$ and silanization prior to cementation provided higher bond strength when compared with air particle abrasion with 110µm $Al_2O_3$ and silanization.

Although Hydrofluoric acid worked very well in terms of getting high bond strength on glass matrix ceramics, the results were poor when it was used for conditioning the reinforced ceramics as it showed the least mean shear bond strength.

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