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Adhesion to a Zirconia-reinforced Lithium Silicate Ceramic: Effects of Ceramic Surface Treatments and Resin Cements

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Clinical Relevance

The bond strength of CAD/CAM zirconia-reinforced lithium silicate (ZLS) glass-ceramic is influenced by applying different ceramic surface treatments and using different types of resin cements. Such steps need to be carefully selected to achieve an optimized adhesion to the ZLS ceramic.

SUMMARY

Objective: This study had the objective to test the effect of ceramic surface treatments on the microshear bond strength (μSBS) of different resin cements to a zirconia-reinforced lithium silicate (ZLS).

Methods and Materials: ZLS blocks were sectioned, embedded in acrylic resin, and then allocated into nine groups considering two study factors: "ceramic surface treatment" (HF - hydrofluoric acid; EP - self-etching primer; TBS - tribochemical silica coating) and "resin cements" (nMDP - without MDP monomer; MDP - with MDP monomer; SA - self-adhesive). Starch tubes (n=36) were placed on the treated ceramic surface and the cement was applied. Starch tubes were removed after 24 hours of storage, and the specimens were thermocycled

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http://doi.org/10.2341/20-226-L

(5,000×; 5°C-55°C). Next, the μSBS test was performed using the wire-loop technique, and topographic and failure analyses were performed.

Results: The factors "ceramic surface treatment" and "resin cement" statistically influenced the μSBS results. Considering the surface treatment factor, the TBS produced statistically lower values when the MDP resin cement was applied, being only similar to the MDP plus EP group. For the resin cement factor, no difference was found for nMDP and SA groups, apart from the surface treatments. Failure analysis showed that the groups treated with EP had a greater number of pre-test failures. The surface treatments induced noteworthy topographic alterations when compared to control (no treatment).

Conclusion: The ZLS ceramic surface treatment with tribochemical silica coating associated with the MDP-containing resin cement resulted in lower bond strength values.

INTRODUCTION

Monolithic ceramic restorations have been widely used with current advances in dentistry, mainly through the development of Computer-Aided Design/Computer-Aided Machining (CAD/CAM) technology, which has enabled clinicians to provide precise high-quality ceramic restorations.[1,2] Zirconia-reinforced lithium silicate (ZLS) glass-ceramic is a good option for a variety of clinical applications, since it provides good aesthetic and mechanical performance.[3] This material is a glass-ceramic reinforced by lithium-metasilicate (Li_2SiO_3) crystals with zirconia crystals (ZrO_2; 8-14 wt%)[4] dissolved in the glassy matrix.[5,6]

Ceramics should have good bonding strength to resin cements in addition to good mechanical properties to provide long-term success of full-contour ceramic restorations. In this sense, the surface treatment of glass-ceramics plays an important role. This procedure improves the surface-free energy, increasing the surface wettability for the cements, in turn favoring the micromechanical and chemical bonding between the resin cement and glass-ceramics.[7,8]

Hydrofluoric (HF) acid etching of glass-ceramics is well established in the literature as an effective surface treatment, since it selectively dissolves the vitreous matrix, creating micropores on the surface into which the resin cement penetrates, promoting mechanical interlocking.[2,9] In addition, the exposure of the silica crystals interacts with the silane agent which is copolymerized with methacrylate groups of the resin cement's organic matrix.[10] However, according to Al-Thagafi and others,[11] tribochemical silica coating by air-abrasion silica-coated alumina particles presents superior bond strength results compared to 5% HF etching with ZLS ceramic. In this sense, tribochemical silica coating would be a good alternative for ceramic surface treatment.[12]

Another surface treatment is self-etching ceramic primers (all-in-one approach) which have emerged as a less toxic and easy-to-apply technique that enables surface etching and silanization in one single step, reducing the clinical time and technical sensitivity.[13] These primers also selectively etch the ceramic surface, however different from HF acid etching. These primers only promote small changes in the ZLS ceramic surface,[7] which may impair the interlocking of resin cement tags with the ceramic surface.[14]

In addition to an efficient surface treatment, the cement is also important for long-lasting tooth/restoration bonding.[15] In an attempt to provide easy and fast handling, as well as a less-sensitive bonding technique, distinct simplified resin cement systems (ie, self-adhesive) have emerged in addition to conventional resin cements. Self-adhesive resin cements bond to the dental substrate without the need for pretreating the tooth, since they enable chemical bonding between the self-adhesive resin and the hydroxyapatite,[16,17] but still require a ceramic surface pretreatment.[18]

On the other hand, conventional resin cements require a bonding agent between their resinous matrix and the dental surface.[19] Furthermore, some cements have bifunctional phosphate monomers (ie, 10-methacryloxydecyl dihydrogen phosphate — 10-MDP) in their composition which chemically bond to the ceramic surface's oxides through a phosphate ester group,[17] and to the resin matrix of the cement through a methacrylate group.[20] Although some studies indicate that MDP-containing resin cements show good performance in the bond strength to different ceramic materials,[21-23] according to Secilms and others,[24] a conventional resin cement without MDP presented better bond strength results than a cement with MDP. However, there is a lack of studies in the literature evaluating adhesion to ZLS ceramics exploring the effects of surface treatments and distinct resin cements to evidence the adhesion outcome when combining these two factors.

Thus, as the literature is still inconclusive about this important topic which plays a relevant clinical role for ceramic performance under clinical service, the purpose of this *in vitro* study was to evaluate the influence of ceramic surface treatments on the microshear bond strength of different resin cement systems to a zirconia-reinforced lithium silicate glass-ceramic. The null hypotheses were: 1) the surface treatments and 2) the resin cement type would not influence the final bond strength results.

METHODS AND MATERIALS

The main information about the materials used in this study is described in Table 1.

Preparation of Ceramic Specimens

A total of 27 rectangular slices (14×12×1 mm^3) were cut from zirconia-reinforced lithium silicate glass-ceramic blocks (18×14×12 mm^3; Vita Suprinity, Vita Zahnfabrik, Bad Säckingen, Germany) with a diamond blade in a cutting machine (Isomet 1000, Buehler, Lake Bluff, Illinois, USA) under constant water cooling. The slices were manually polished on both sides with silicon carbide papers having different grit sizes (#400, #600, and #1200-grit; Norton Abrasives, Saint-Gobain; São Paulo, SP, Brazil). Next, one side (bonding surface) of each specimen was manually ground (15 times in each axis, *x* and *y*) with a #60-grit size silicon carbide sandpaper (Norton Abrasives, Saint-Gobain) by applying light finger pressure to simulate the roughness obtained from CAD/CAM milling, thus providing a mean roughness (Ra=1.98 μm and Rz=12.88 μm)

Table 1: Materials Used in the Study and Respective Characteristics (Commercial Name, Manufacturer, and Chemical Composition)

Material and Manufacturer	Composition
Zirconia-reinforced lithium silicate glass-ceramic (VITA Suprinity, VITA Zahnfabrik, Bad Säckingen, Germany)	SiO_2; Li_2O; K_2O; P_2O_5; ZrO_2; Al_2O_3; CeO_2; pigments
Hydrofluoric acid 5% (IPS Ceramic Etching-gel, Ivoclar, Schaan, Liechtenstein)	Hydrofluoric acid < 5%
Self-etching ceramic primer (Monobond Etch & Prime, Ivoclar)	Tetrabutyl ammonium dihydrogen trifluoride, methacrylated phosphoric acid ester, trimethoxysilylpropyl methacrylate, alcohol, water
30 µm silica-coated alumina particles (CoJet Sand, 3M ESPE, Seefeld, Germany)	Aluminum oxide. Free amorphous synthetic silica
MDP-free conventional resin cement (Multilink Automix, Ivoclar)	Base: ytterbium trifluoride, ethoxylated bisphenol A dimethacrylate, Bis-GMA, 2-HEMA, 2-dimethylamanoethyl methacrylate. Catalyst: ytterbium trifluoride, ethoxylated bisphenol A dimethacrylate, urethane dimethacrylate, 2-HEMA, dibenzoyl peroxide and silica filler (68 wt%),[25] pigments
MDP-containing conventional resin cement (Panavia F 2.0 - Kuraray Noritake, Ukayama, Japan)	10-methacryloxydecyl dihydrogen phosphate, bisphenol-A-polyethoxy dimethacrylate, hydrophobic aliphatic methacrylate, hydrophilic aliphatic methacrylate, silanated silica filler, silanated barium glass filler (78 wt%),[26] sodium fluoride
Self-adhesive resin cement (RelyX U200 - 3M ESPE)	Base paste: Methacrylate monomers containing phosphoric acid groups, Methacrylate monomers, silanated fillers, initiator components, stabilizers, rheological additives. Catalyst paste: Methacrylate monomers, alkaline (basic) fillers, silanated fillers (72 wt%),[27] initiator components, stabilizers, pigments, rheological additives
Silane coupling agent (Prosil - FGM, Joinville, Brazil)	3-methacryloxipropyltrimethoxysilane (<5%); ethanol (>85%); water (<10%)

Abbreviations: Bis-GMA, bisphenol-A-diglycidylether dimethacrylate; HEMA, hydroxyethyl methacrylate.

before crystallization similar to the intaglio surface of CAD/CAM milled restorations.[28] The specimens were washed in an ultrasonic bath (1440 D, 50/60 Hz, Odontobras, Ind And Com Equip Med Odonto LTDA, Ribeirão Preto, Brazil) with distilled water for 10 minutes, air-dried for 30 seconds, and crystallized in a specific furnace according to the manufacturer's instructions (VACUMAT 6000 MP, Vita Zahnfabrik, 840°C, 8 min vacuum).

Each ceramic slice was embedded in a cylindrical polyvinyl chloride (PVC) mold using a self-cured acrylic resin (VIPI Flash, Pirassununga, Brazil). For this, a double-sided tape (3M Sumare, Brazil) was used to keep the bonding surface free for cementation. After the final polymerization of the acrylic resin, the specimens were washed in an ultrasonic bath (as previously reported) to remove any glue residue. The slices were randomly assigned (www.randomizer.org) into nine groups (three ceramic slices per group) according to the study factors: surface treatment and type of resin cement, as shown in Table 2.

Ceramic Surface Treatments

Hydrofluoric Acid Etching (HF)—Hydrofluoric acid (5% IPS Ceramic Etching Gel, Ivoclar, Schaan, Liechtenstein) was applied and scrubbed on the ceramic surface with a microbrush for 20 seconds. As recommended by the manufacturer, the specimens were washed with air/water-spray for 30 seconds, then subjected to an ultrasonic bath (1440D, Odontobras) with distilled water for 5 minutes, and air-spray dried for 30 seconds. A silane coupling agent (Prosil, FGM, Joinville, Brazil) was actively applied with a microbrush for 15 seconds, kept to react for 60 seconds, and gently air-spray dried for 15 seconds.

Etch and Prime Ceramic Primer (EP)—The self-etching ceramic primer (Monobond Etch & Prime, Ivoclar) was actively applied on the ceramic surface with a microbrush for 20 seconds, kept to react for 40 seconds, washed with air/water-spray for 20 seconds, and air-spray dried for 30 seconds.

Tribochemical Silica Coating (TBS)—The tribochemical silica coating was performed with 30 μm silica-coated aluminum oxide particles (CoJet Sand, 3M ESPE, Seefeld, Germany) using a micro-etcher (DENTO-PREP microblaster, Ronvig, Daugaard, Denmark) at a distance of 15 mm from the device's nozzle to the ceramic surface with a pressure of 2.5 bar[29] in oscillatory movements for 15 seconds.[11] A gentle air-spray was subsequently applied to remove the loose particles, and a silane coupling agent (Prosil, FGM) was actively applied for 15 seconds, kept to react for 60 seconds, and gently air-spray dried for 15 seconds.

Table 2: *Study Design and Study Groups*

Surface Treatments	Resin Cements	Group Codes
5% hydrofluoric acid etching (IPS Ceramic etching-gel) + Silane (Prosil) - HF	Multilink Automix - nMDP	nMDP+HF
	Panavia F 2.0 - MDP	MDP+HF
	RelyX U200 -SA	SA+HF
Self-etching ceramic primer (Monobond Etch & Prime) - EP	Multilink Automix - nMDP	nMDP+EP
	Panavia F 2.0 - MDP	MDP+EP
	RelyX U200 -SA	SA+EP
Tribochemical silica coating (CoJet Sand) + Silane (Prosil) - TBS	Multilink Automix - nMDP	nMDP+TBS
	Panavia F 2.0 - MDP	MDP+TBS
	RelyX U200 -SA	SA+TBS

Abbreviations: nMDP, MDP-free conventional resin cement; MDP, MDP containing conventional resin cement; SA, self-adhesive resin cement; HF, 5% hydrofluoridric acid; EP, self-etching ceramic primer; TBS, tribochemical silica coating

Microshear Resin Cement Sample

After the ceramic surface treatment, starch tubes (Renata, Pastificio Selmi, Londrina, Brazil) with 1.0 mm of height and 0.96 mm of internal diameter were placed on the treated ceramic surface and fixed at their external surface with sticky wax (Lysanda, São Paulo, Brazil) to keep them in position (n=36; 12 starch tubes in each ceramic slice, with 3 ceramic slices for each group).[30]

The adhesive procedures were performed at room temperature (25°C) by a single trained operator, and the resin cements were manipulated and applied according to the manufacturer's recommendations, as follows.

MDP-Free Conventional Resin Cement (nMDP- Multilink Automix)—The resin cement base and catalyst pastes were dispensed from the double-push syringe, then mixed for 20 seconds resulting in a homogeneous mixture, and inserted with a probe into the starch tubes.

MDP-Containing Conventional Resin Cement (MDP-Panavia F2.0)—The resin cement base and catalyst pastes were dispensed from the syringes, then mixed for 20 seconds resulting in a homogeneous mixture, and inserted with a probe into the starch tubes.

Self-Adhesive Resin Cement (SA - RelyX U200)—The resin cement base and catalyst pastes were dispensed from the double-push syringe, then mixed for 20 seconds resulting in a homogeneous mixture, and inserted with a probe into the starch tubes.

The resin cement excesses were carefully removed with a microbrush. The cement of each starch tube was then light-activated (1200 mW/cm^2 of intensity, Radii Cal, SDI, Bayswater, Australia) for 40 seconds, and the specimens were stored in distilled water in a laboratory incubator at 37°C for 24 hours. The starch tubes were then carefully removed with a clinical probe. The adhesive interface of all the samples was analyzed in a stereomicroscope (Stereo Discovery V20, Carl-Zeiss, Gottingen, Germany) to inspect the integrity of the adhesive zone, and the samples presenting any bubbles or defects were discarded and replaced.

Aging—Thermocycling

After storage for 24 hours, all specimens underwent intermittent 5000 thermal-cycles (Ethik Technology Limited — model 521-6D; Vargem Grande Paulista, SP, Brazil) with the temperature ranging from 5°C to 55°C with 30 seconds of dwell time at each temperature and 4 seconds of transfer time.[3]

Microshear Bond Strength Test—Wire-Loop Method

The PVC cylinders were placed in a jig attached to a universal testing machine (Emic DL1000, São José dos Pinhais, Brazil) so that the cement cylinder was in alignment with the center of the load cell, being parallel to the adhesive interface. A stainless-steel wire (Ø=0.20 mm) was looped around the specimen cylinder parallel to and as close as possible to the cement-ceramic interface. The shear load was applied (10 N load cell) at a rate of 0.5 mm/min until failure occurred, and the data were recorded in MPa.

Failure Analysis

All tested specimens were inspected in a stereomicroscope (Discovery V20, Carl-Zeiss, Gottingen, Germany) with 10-50× magnification to verify the failure type. The failures were classified as adhesive (less than 50% of resin cement remained at the adhesive interface) or cohesive (more than 50% of resin cement remained in the adhesive interface). Representative samples were selected and analyzed in a scanning electron microscope (SEM) (Secondary electrons, 20kV; VEGA3, Tescan, Brno, Czech Republic) at 100× and 230× magnification.

Topographic Analysis

Two additional specimens of each group were produced, treated as mentioned above, dried in a laboratory desiccator, and gold-sputtered to be analyzed in an SEM (Secondary electrons, 20kV; VEGA3, Tescan) to evaluate the ceramic surface characteristics after the distinct treatments.

Data Analysis

According to normality (Shapiro-Wilk) and homoscedasticity (Levene's) tests, the data were nonparametric and heterogeneous. Thus, the bond strength was analyzed using the Kruskal-Wallis nonparametric test and Dunn's post-hoc test at a significance level of 0.05. The samples having cohesive or pre-test failures were disregarded from the study and the data analysis. Each cement cylinder was defined as an experimental unit, and the sample size was 36 for each testing group (n=36).

RESULTS

According to the Kruskal-Wallis ($p<0.001$) and Dunn`s tests (standard error for comparison: 16.648 to 22.942; critical Z value: 3.197; critical value for comparison: 53.223 to 73.346), the microshear bond strength results were statistically influenced by the ceramic surface treatment and by the resin cement factors. The tests showed that there was no statistical difference between nMDP and SA resin cements, regardless of the surface treatment used. However, for the conventional resin cement containing MDP, the surface treatment with HF etching promoted the highest bond strength values (mean: 7.22; median: 6.13 MPa), being statistically similar to EP (mean: 5.27; median: 5.78 Mpa), that was similar to TBS (mean: 2.63; median: 1.77 Mpa). Comparing the resin cements when applying the same ceramic surface treatment, there was only one difference when the MDP cement was used with TBS, which presented statistically lower values than the other groups (mean: 2.63; median: 1.77 MPa) (Table 3)— although it presented the highest standard deviation proportionally in relation to the mean of the study.

Failure at the adhesive zone ("adhesive") was the main type of failure of the samples. (Figures 1 and 2). However, the groups treated with the self-etching ceramic primer showed a considerably higher number of pre-test failures due to debonding (failure at the ceramic-resin interface) (Figure 1), especially the group MDP+EP. The group that presented the highest number of cohesive failures was the SA+HF, having no pre-test failure.

In terms of topographic changes, tribochemical silica coating created a more irregular surface, introducing sharper flaws and scratches. The hydrofluoric acid etching promotes alterations at the nanoscale by removing the nanometric grains, while the self-etching

Table 3: *Mean, Standard Deviation (SD), and Median (First and Third Quartiles - Q1-Q3) Values of Microshear Bond Strength in MPa (Kruskal-Wallis and Dunn's Post-Hoc Tests)*

Resin Cements	Means and Medians	Surface Treatments[a]		
		HF	EP	TBS
nMDP	Mean (SD)	6.48 (3.86) Aa	5.07 (2.48) Aa	8.54 (4.01) Aa
	Median (Q1-Q3)	4.97 (4.4- .81)	4.71(3.65-6.62)	8,76 (5.99-11.33)
MDP	Mean (SD)	7.22 (4.04) Aa	5.27 (4.21) ABa	2.63 (2.62) Bb
	Median (Q1-Q3)	6.13 (4.4-9.25)	5.78 (0.53-9.25)	1.77 (0.74-3.6)
SA	Mean (SD)	11.93 (6.8) Aa	10.1 (7.11) Aa	7.1 (3.85) Aa
	Median (Q1-Q3)	9.1 (7.12-19.27)	9.21 (2.96-16.49)	6.53 (3.69-10.01)

Abbreviations: nMDP, MDP-free conventional resin cement; MDP, MDP containing conventional resin cement; SA, self-adhesive resin cement; HF, 5% hydrofluoridric acid; EP, self-etching ceramic primer; TBS, tribochemical silica coating.

[a]*Different uppercase letters show statistically significant differences between surface treatments for the same resin cement (p<0.05) (lines). Different lowercase letters show statistically significant differences between the resin cements for the same surface treatment (p<0.05) (columns).*

ceramic primer (mild acid) induces lower topography alterations (Figure 3).

DISCUSSION

The null hypotheses were rejected once the bond strength to a ZLS ceramic was directly influenced by the surface treatment and the type of resin cement applied. The worst scenario in terms of adhesive strength of ZLS ceramics occurred when treating with the silica coating tribochemical method and luting with the resin cement containing MDP concomitantly.

The groups treated with Monobond Etch & Prime—which is composed of a silane, a ceramic agent, and a priming agent (Table 1) in a single bottle—produced statistically similar results to the HF etching, regardless of the cement used, corroborating the results presented in the literature.[13,31,32,33] However, all groups that received this surface treatment had the highest number of pre-test failures (Table 3; Figure 1). This can be corroborated by the topography images of the ceramic that show a different result between both treatments (EP and HF). This demonstrates that the initial characteristics (CAD/CAM milling simulation) remain after EP surface treatment, while HF etching promoted dissolution of the surface glassy matrix, thereby removing the defects created by the milling simulation and more uniformly exposing the ceramic glassy matrix, making the surface more reactive and prone to adhesion with the resin cements (Figure 3). Prado and others[34] also observed a greater number of pre-test failures for a lithium disilicate and a feldspathic ceramic treated with such ceramic primer, but they have also observed that the Monobond Etch & Prime self-etching ceramic primer produced stable bonding after aging.

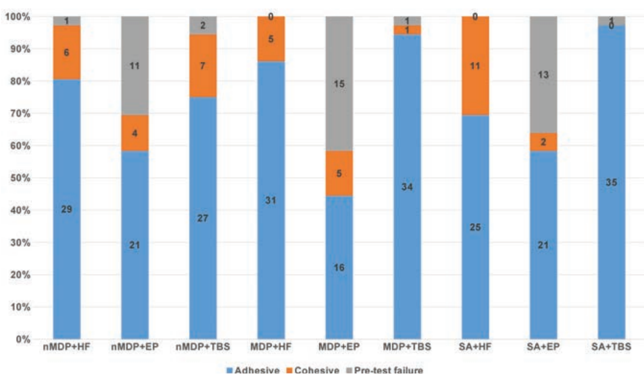

Figure 1. *Number and percentage for types of failure and pre-test failures of each experimental group submitted to the microshear bond strength test.*

Tribochemical silica coating treatment showed similar bond strength values to HF for the MDP-free conventional and self-adhesive resin cements. Al-Thagafi and others[11] also found an improvement in adhesive strength using the tribochemical silica coating (CoJet Sand, 3M ESPE) followed by silanization of the ZLS ceramic, however using this protocol for the repair of the ceramic with composite resin. Yet, Sato and others[29] showed a significant decrease in the bond strength after thermocycling when the zirconia-reinforced lithium silicate ceramic was treated with tribochemical silica coating (CoJet Sand), suggesting that this surface treatment does not provide a stable bond. Altan and others[35] also concluded that the surface treatment with tribochemical silica coating is not as effective as the HF etching in terms of bond strength to the ZLS ceramic. In addition, a rougher

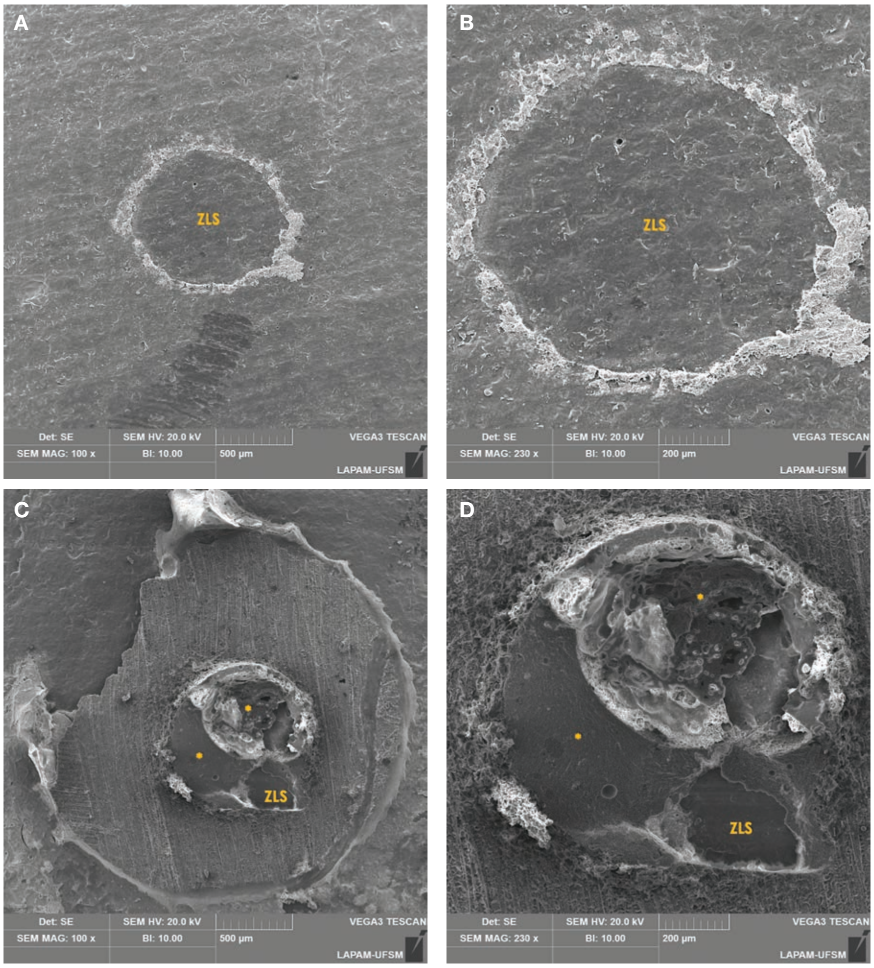

Figure 2. *SEM images (100× and 230× of magnification) of the different types of failure after the microshear bond strength test: adhesive (A-B) and cohesive (C-D). ZLS (zirconia-reinforced lithium silicate ceramic); '*' remnant of the resin cement.*

ceramic surface, such as that presented by the air-abraded groups (Figure 3), can have a deleterious effect on mechanical properties when defects are not properly filled by the adhesive bonding.[36-38]

The bonding between two materials does not depend only on the size of the irregularities created for the surface treatment, but also on the ability of cements to infiltrate them.[10] No statistical difference was found between MDP-free and self-adhesive resin cements used in the study, regardless of the surface treatment applied (Table 3). The lowest value of bond strength was observed when the MDP-containing conventional resin cement was used in association with the TBS surface treatment, being statistically similar to EP (Table 3) for the same cement. Zeller and others[39] found that a conventional resin cement with MDP has a higher viscosity at the beginning of its manipulation at room temperature (23°C), which decreases during the temperature increasing (37°C = mean oral temperature), simulating the manipulation and clinical adjustments during cementation of a restoration. However, in *in vitro* studies, this increase in temperature does not happen, maintaining the increased viscosity of the resin cement during its handling, which can hinder its penetration into the roughness created by the air-abrasion (Figure 3).

The majority of failures found between the groups were adhesive, however, the EP groups (nMDP+EP, MDP+EP, SA+EP) showed the highest number of pre-test failures, which is considered the main limitation of this study. This may be explained due to the lower chemical interaction between this surface treatment and the resin cements, which may preclude a durable micromechanical bonding.[34,40] These failures were disregarded from statistical analysis, which may have overestimated the bond strength values of the EP groups since no value was given to the pre-test failures[41,42] because they increased the standard deviation. Therefore, the analysis of the data of the EP groups should be used with caution.

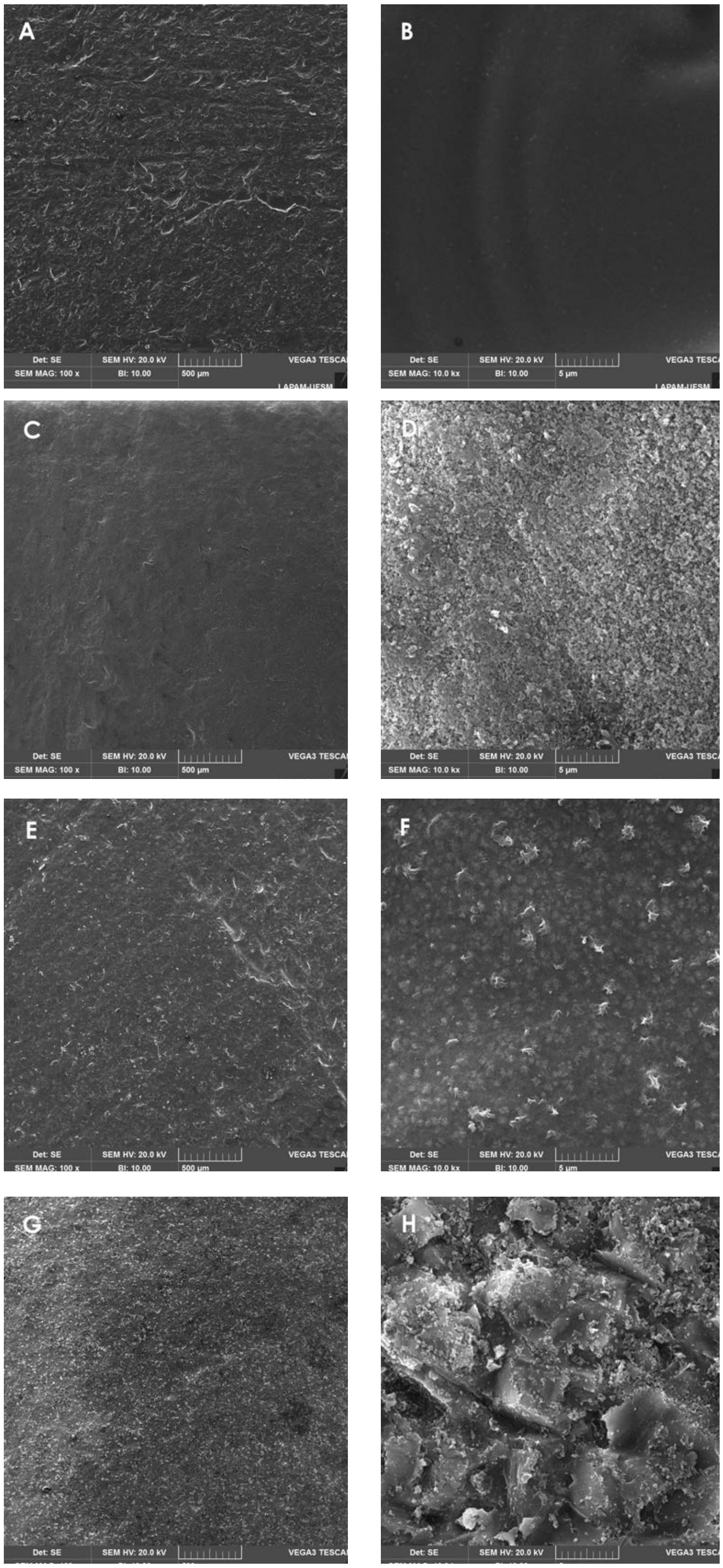

Figure 3. *Topographic images on scanning electron microscopy (100× and 10,000× of magnification) of the ceramic surface on control (CAD/CAD milling simulation, without surface treatment) and the surface treatments: Control (A-B); 5% hydrofluoric acid etching (HF) (C-D); self-etching ceramic primer (EP) (E-F); and tribochemical silica coating (TBS) (G-H).*

Another limitation was the number of cohesive failures. According to Braga and others,[41] such failures are explained by the test mechanics and fragility of the materials involved. Della Bona and van North[43] showed that the microshear bond strength test creates a non-homogeneous load distribution at the interface, which is associated with distal failures in the adhesive interface. Furthermore, cohesive failures often mean that the bond within the material itself is weaker than the bond at the interface,[24] justifying the high microshear bond values in such groups. Thus, in order not to overestimate the bond strength to the material, the values of cohesive failures were not included in the statistical analysis.

Future *in vitro* studies should be conducted to assess other bonding approaches by exploring distinct resin cements, adhesive agents, and glass-ceramics.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be made:

- The bond strength to the zirconia-reinforced lithium silicate glass-ceramic is significantly influenced by the ceramic surface treatment performed and the resin cement used.
- The surface treatments with hydrofluoric acid and ceramic primer were similar to each other regardless of the resin cement used.
- The performance of resin cement without MDP and self-adhesive were similar to each other, regardless of the surface treatment used.
- Using the MDP-containing resin cement after treating the ceramic surface with the tribochemical silica coating method resulted in lower bond strength values among the tested conditions.

Acknowledgments

This work is part of the fullfillment for the requirements of the MS degree (FDN) in the Post-Graduate Program in Oral Sciences at the Faculty of Dentistry of the Federal University of Santa Maria-RS, Brazil. Moreover, the authors declare no conflicts of interest and emphasize that this study was partly financed by the Brazilian Federal Agency for Coordination of Improvement of Higher Education Personnel - CAPES (Finance Code 001). We especially thank Ivoclar for donating the research materials, and finally we emphasize that those institutions had no role in the study design, data collection or analysis, decision to publish, or in preparing the manuscript.

Conflict of Interest

The authors have no financial interest in any of the companies or products mentioned in this article

(Accepted 4 June 2021)

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