



Original article

Influence of different cleaning procedures on the shear bond strength of 10-methacryloyloxydecyl dihydrogen phosphate-containing self-adhesive resin cement to saliva contaminated zirconia

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Abstract

Purpose: To evaluate the effect of different cleaning methods on the shear bond strength (SBS) of a 10-methacryloyloxydecyl dihydrogen phosphate (MDP)-containing self-adhesive resin cement to zirconia after saliva contamination.

Methods: Sixty zirconia specimens were randomly divided into four groups (n=15) according to treatment surface. Except for the control group, all samples were contaminated with saliva and were then rinsed with water-spray and air-dried. Subsequently, the specimens were either treated with a cleaning paste (CP), with argon plasma (AP), or did not undergo an additional cleaning process (WS). An MDP-containing self-adhesive resin cement was applied onto the ceramic surfaces. Specimens were stored in water (24 hours) followed by thermocycling (5°C to 55°C for 10,000 cycles). SBS tests were performed in a universal testing machine, and the results (MPa ± SD) were statistically analyzed using ANOVA and Bonferroni post-hoc test. Fractured surfaces were examined to identify the failure types using a stereomicroscopy and SEM.

Results: The surface cleaning treatment ($p < 0.05$) significantly affected the results. The highest SBS values were observed in the control group (12.16 ± 1.22 MPa) and were statistically comparable to values for the CP group (11.38 ± 1.65 MPa). The AP group (9.17 ± 1.06 MPa) showed significantly higher bond strength than the WS group (6.95 ± 1.20 MPa), but it showed significantly lower strength than the control and CP groups.

Conclusions: The CP application was the most effective method in removing saliva contamination. The AP treatment could not restore the SBS to the same level as uncontaminated specimens.

Keywords: Argon plasma treatment, Cleaning paste, Saliva contamination, Shear bond strength, Y-TZP

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1. Introduction

Yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) ceramics have been widely used in prosthetic dentistry due to their high biocompatibility, excellent mechanical properties, and suitable optical behavior [1,2]. In addition, developments in dental computer-aided design and computer-aided manufacturing (CAD/CAM) technology have contributed to the popularity of zirconia ceramics, whether as framework material or fully anatomical alternative [2]. In recent years, growing demand for tooth-colored restorations, improvements in formulations, ease of processing, and reduced laboratory costs have encouraged an increase in the number of zirconia-based restorations [3].

Although the use of adhesive cementation is not mandatory for Y-TZP restorations due to their high flexural resistance, it is recommended for ensuring better retention and marginal seal [4-6]. The traditional adhesive techniques used with silica-based ceramics cannot be applied to these polycrystalline materials that do not contain a glass phase [7]. Alternatively,

different mechanical and chemical surface pretreatments have been recommended to improve the bonding of composite cement to zirconia. Among these, the application of products containing the phosphate ester monomer 10-methacryloyloxydecyl dihydrogen phosphate (MDP) after airborne-particle abrasion results in better Y-TZP bonding [8-11].

Due to their ease of use, self-adhesive resin cements are commonly employed to adhere restorative materials to teeth [12]. These products were designed to combine the one-step application of conventional cements with the improved mechanical properties and bonding capability of the resin cements [13]. The main advantage of self-adhesive cements is that they do not require any pretreatment of the tooth surface because of presence of carboxylic or phosphoric acid-functionalized monomers, which are utilized to achieve enamel and dentin demineralization [14]. Although such cements are intended for use without any additional conditioning of the restoration surface, there is a great variation in their chemical compositions and some of them have shown a better bond to zirconia after airborne-particle abrasion and the application of a separate ceramic primer [11,15]. Self-adhesive resin cements that contain functional monomers such as MDP or 4-methacryloxyethyl trimellitic anhydride (4-META) have demonstrated an acceptable bond durability to air-abraded Y-TZP without pre-priming [16-18]. However, information about the bonding mechanisms of different commercially available self-adhesive cements to zirconia is still insufficient.

To ensure successful adhesive cementation, the ceramic surface must be free from any contamination. During the try-in procedure, the intaglio bonding surface of the restoration may come into contact with saliva,

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blood, or fitting indicators, which may weaken the resin-ceramic bond [19–23]. Saliva contamination of pretreated zirconia is one of the main reasons for decreased or failed bond strength [23–34], which leads to poor marginal adaptation, causing microleakage, loss of retention, and decreases fracture resistance of the restored tooth and the restoration [4, 6]. Due to these problems, different cleaning methods have been developed to eliminate contaminants and obtain an optimal surface for adhesion.

Methods, such as rinsing with water, immersing in acetone or isopropanol, or cleaning with ethanol, have been reported to be ineffective in removing saliva residues from Y-TZP ceramics [24–34]. Airborne-particle abrasion with 30 to 50 µm alumina or silica-coated alumina particles has proven to be an effective method of eliminating any type of contaminants (saliva, blood or silicone disclosing medium) from zirconia surfaces [24–27,29–31,35]; however, sandblasting has been associated with the creation of microcracks and structural defects, which might negatively affect the mechanical properties of Y-TZP materials [36–38]. Alternatively, nonabrasive cleaning solutions have been developed to decontaminate the bonding surfaces of prosthetic restorations after intraoral try-in [23,28–31,34,35]. These products contain a high concentration of active agents (zirconium oxide particles, potassium hydroxide, or MDP ammonium salt), which attract phosphate contaminants by chemical gradient, leaving behind a clean surface. Several studies have demonstrated that a commercial cleaning paste shows a good efficiency in removing saliva from zirconia ceramics [28–31,34].

In recent years, plasma technology has been introduced to enhance the performance of biomaterials [39]. Plasma is defined as a partially or wholly ionized gas, composed essentially of electrons and heavy species (ions and neutral particles), possessing a net neutral charge. There are two types of plasma based on how they are produced: thermal and nonthermal plasma [40]. Thermal plasma is obtained at high pressure and temperature and presents a local thermodynamic equilibrium. In contrast, nonthermal plasma is generated under atmospheric or reduced pressures (vacuum) at temperatures of 30–60°C and is characterized by a difference in the energetic levels of electrons and heavy particles. This method has been shown to be effective in optimizing the surface properties of materials, such as metals, ceramics, or polymers, at relatively low temperatures, without affecting their bulk characteristics [39,40]. In dentistry, nonthermal argon plasma treatment has shown promising results for increasing resin bonding to Y-TZP ceramics [41–43]. Argon plasma application increases the polar component of substrate, leading to a more hydrophilic surface with better wettability [41]. In addition to improving adhesion, plasma technology is also used to eliminate contaminants [44]. Its cleaning mechanism depends on the gas used. Inert gases, such as argon or neon, remove contaminants off the substrate by physical sputtering. However, reactive gases, such as oxygen or hydrogen, dissolve impurities by chemical reduction. Previous studies have shown that different nonthermal plasmas are effective in removing salivary contamination from the bonding surface of zirconia [32,33]. Nevertheless, the cleaning effect of plasma has not yet been compared to that of a cleaning paste on saliva contaminated Y-TZP specimens. Furthermore, there are no data regarding the bond between MDP-containing self-adhesive resin cements and zirconia ceramics subjected to contamination and cleaning.

Therefore, the objective of this *in vitro* study was to evaluate the effect of different cleaning methods on the artificially aged shear bond strength (SBS) of an MDP-containing self-adhesive resin cement to Y-TZP ceramic after saliva contamination. The null hypothesis tested was that the surface cleaning procedures would not affect the SBS of resin cement to zirconia.

2. Material and methods

2.1. Sample preparation

Materials tested in this study are summarized in Table 1. Based on data from a pilot study, the sample size was calculated using specific software (G*Power version 3.1.9.6 for Mac OS X, Heinrich Heine University, Düsseldorf, Germany). To detect a difference of 10%, using a power of 80% and an alpha value of 0.05, the required sample size was 15 specimens per group. Three presintered discs of Y-TZP ceramic (Metoxit Z-CAD

Table 1. The brands, compositions, and batch numbers of the materials used in this study.

Material	Composition	Batch No.
Metoxit Z-CAD HD99-10	ZrO ₂ , HfO ₂ , Y ₂ O ₃ , Al ₂ O ₃	405454
Tab 2000 (Medium powder and fast set liquid)	Methyl methacrylate, n-butylmethacrylate	6314204
Ivoclean	Zirconium oxide, water, polyethylene glycol, sodium hydroxide, pigments, additives	Y43218
Panavia SA Cement Universal (Shade A2 Universal)	MDP, bis-GMA, TEG-DMA, HEMA, hydrophobic aromatic dimethacrylate, silanated barium glass filler, silanated colloidal silica, sodium fluoride, aluminum oxide filler, silane coupling agent, dl-camphorquinone, peroxide, accelerators, catalysts, pigments.	AV0033

Abbreviations: MDP, 10-methacryloyloxydecyl dihydrogen phosphate; bis-GMA, bisphenol A diglycidylmethacrylate; TEG-DMA, triethyleneglycol dimethacrylate; HEMA, 2-hydroxyethyl methacrylate.

HD99-10, Metoxit AG, Thayngen, Switzerland) were sectioned using a water-cooled precision diamond saw (IsoMet 1000 Precision Saw, Buehler, Lake Bluff, IL, USA) to produce parallelepiped specimens (12x10x10mm; N=60). The zirconia specimens were cut 20% larger than the desired dimensions to take into consideration shrinkage and were then sintered at 1500°C for 60 min (Dekema Austromat µSIC, Dekema, Freilassing, Germany) according to the manufacturer's firing instructions. Subsequently, each ceramic sample was embedded in acrylic resin (Tab 2000, Kerr, Bioggio, Switzerland) cylinder mold (16 mm diameter and 16 mm height) leaving a rectangular side uncovered.

The Y-TZP surface of each specimen was polished using a polishing machine (RotoPol-22, Struers, Copenhagen, Denmark) with silicon carbide paper discs (26 microns followed by 18 microns) for 120 seconds under constant water irrigation. Debris on the surface were removed using 99% ethanol in an ultrasonic cleaner (Mestra, Vizcaya, Spain) for 3 minutes. Next, airborne-particles abrasion with 50 µm Al₂O₃ at 2 bar pressure was applied on the all samples for 15 seconds from a distance of 10 mm. The specimens were further ultrasonically cleaned in 99% ethanol for 3 minutes and then carefully dried in an air blast.

2.2. Surface cleaning methods

The samples were randomly divided into four study groups (n=15): control group, water spray (WS) group, cleaning paste (CP) group, and argon plasma (AP) group. Randomization was performed by random number generator software (Random Number Generator, Elements Software, Leicester, United Kingdom). Except for the control group, all specimens were contaminated with fresh human saliva obtained from a healthy male donor who had not consumed any food or drinks 1.5 hours prior to the collection procedure. Ten minutes prior to collection, the volunteer rinsed his mouth with clean water for 30 seconds to remove desquamated epithelial cells, microorganisms, and possible food and drink remnants [45,46]. All experiments were performed using fresh saliva collected on the same occasion. The local ethical committee (University Complutense of Madrid, Madrid, Spain, No:18/73-E) approved the protocol and the donor signed informed consent to participate in the study.

The saliva was applied onto the ceramic surfaces and spread with a microbrush for 1 minute [34]. Afterwards, the specimens were rinsed with water-spray for 30 seconds and air-dried for another 30 seconds. In WS group, no further cleaning was performed. In CP group, a cleaning paste (Ivoclean, Ivoclar Vivadent, Schaan, Liechtenstein) was applied for 20 seconds using a microbrush, followed by rinsing with water-spraying for 30 seconds and air-drying for another 30 seconds, according to the manufacturer's recommendation. In AP group, specimens were underwent argon plasma treatment in a low-pressure nonthermal plasma system for dental use (Plasma R, Sweden & Martina, Padova, Italy) by applying a

radiofrequency power of 16 W and a working pressure of 150 Pa for 15 minutes. All specimens were transported in dust-proof containers before and after cleaning procedures.

2.3. Bonding procedure

A polytetrafluoroethylene matrix of 4 mm internal diameter and 4 mm internal height was placed on the center of the Y-TZP surface of each sample and filled with an automix self-adhesive resin cement (Panavia SA Cement Universal, Kuraray Noritake Dental, Tokyo, Japan). The luting agent was light-activated from the top and two sides for 20 seconds each with a LED light-curing unit (Elipar DeepCure-S, 3M Oral Care, St Paul, MN, USA), operated in standard mode (1470 mW/cm² light intensity), following the manufacturer's guidelines. After the plastic cylinders were gently removed, the specimens were stored in deionized water at 37°C for 24 hours and aged by thermocycling with 10,000 cycles at 5°C and 55°C in high purity water for 20 seconds each with 10 seconds between baths for thermal stabilization.

2.4. Shear bond strength test and failure analysis

The SBS tests were performed in a universal testing machine (ProDiber, Madrid, Spain) at a cross-head speed of 1 mm/min. A compressive load was applied to the ceramic-resin interface using a mono-bevelled chisel shaped steel tip (Fig. 1) until fracture occurred. The shear bond strength values (MPa) were calculated from the peak load at failure divided by the specimen surface area.

Following debonding, the surface of each zirconia specimen was examined using a stereomicroscope (M-80, Leica, Wetzlar, Germany) at 40x magnification to determine the failure pattern: A, adhesive failure between the ceramic and luting resin; C, cohesive failure within resin cement; or M, a combination of these failure modes (mixed failure) [6,15,18,21,30]. In addition, representative samples for each group were further examined in a scanning electron microscope (SEM) operating at 20 kV (JSM5600, JEOL, Tokyo, Japan). Prior to SEM evaluation, specimens were mounted on metallic platforms, and gold coated under vacuum (Sputter Coater Balzers SCD 004, Bal-Tec, Fürstentum, Liechtenstein) to render them electrically conductive.

2.5. Statistical analysis

Statistical analysis was performed using the software SPSS 25.0 for Windows (IBM Corporation, Armonk, NY, USA). Descriptive statistics, including the mean and the standard deviation, were calculated for each group. The normality of the data was verified by the Kolmogorov-Smirnov test and the assumption of equal variances was tested by using the Levene Median test. The data were submitted to one-way analysis of variance (ANOVA), considering the SBS data (MPa) as the dependent variable and the surface cleaning treatment (4 levels: none, water-spray, cleaning paste, argon plasma) as independent variable. Multiple comparisons were made using Bonferroni post-hoc test. *p* values less than 0.05 were considered to be statistically significant in all tests.

3. Results

The surface cleaning treatment significantly affected the results ($p=0.0001$) (Table 2). The highest bond strength values were observed in the control group (12.16 ± 1.22 MPa) and were statistically comparable to values for the CP group (11.38 ± 1.65 MPa) ($p=0.671$). The AP group (9.17 ± 1.06 MPa) showed significantly higher bond strength than the WS group (6.95 ± 1.20 MPa) ($p=0.0001$), but it revealed significantly lower strength than the control and CP groups ($p=0.0001$). The mean values of SBS, along with standard deviations and minimum and maximum values, are shown in Table 3.

The failure analysis revealed that the control and CP groups mainly exhibited mixed failure modes, showing residue of luting composite resin on the ceramic surface (Fig. 2). The AP group displayed a balanced distribution between adhesive and mixed failure patterns. For WS group,



Fig. 1. Specimen prepared for SBS test placed on the testing machine.

all specimens had adhesive failures to zirconia (Fig. 3). Neither group showed an exclusively cohesive failure type. The results from inspections of the Y-TZP surfaces are presented in Fig 4.

4. Discussion

This study evaluated the effect of different cleaning methods on the artificially aged bond strength of an MDP-containing self-adhesive resin cement to Y-TZP ceramic after saliva contamination. Since the surface cleaning procedures significantly affected the SBS values, the null hypothesis was rejected.

The long-term success of adhesive cementation depends, among other factors, on achieving bonding surfaces free of contaminants [19–23]. Any solid substrate exposed to the oral environment become coated with a thin organic layer of adsorbed salivary biopolymers. This acquired salivary pellicle possesses phosphate groups in the form of phospholipids, which actively bond to the internal surface of zirconium oxide restorations during the clinical try-in phase, rendering this restorative material more inert to the adhesive bonding [22,27]. It has been demonstrated by X-ray photoelectron spectroscopy (XPS) that saliva contamination of zirconia ceramics increases the carbon, oxygen, and nitrogen levels, adversely affecting the optimal interaction between resin cement and ceramic surface [21,25–27]. Therefore, removal of these contaminants is essential to establish a durable adhesion to zirconia.

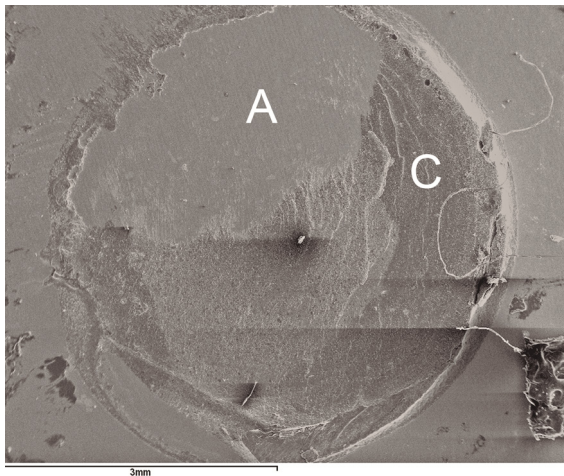
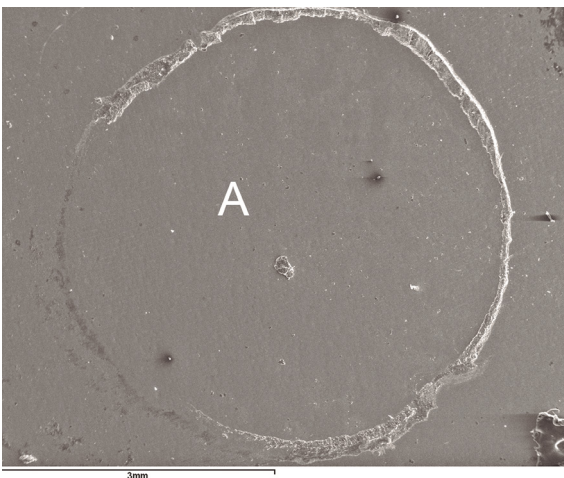
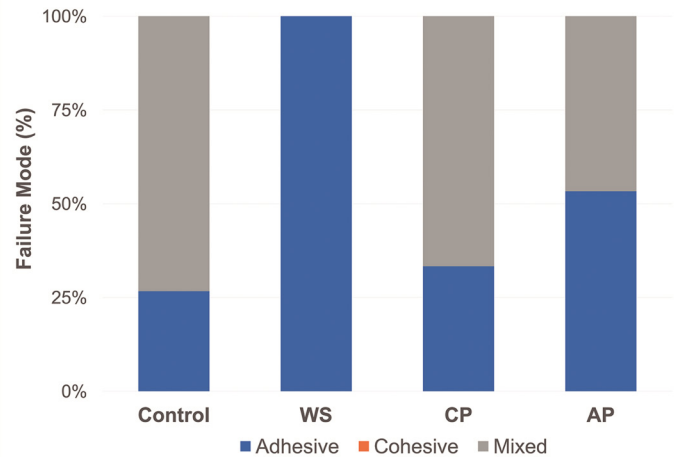
As has been previously reported, airborne-particle abrasion increases the roughness and the surface energy of Y-TZP ceramics, which benefits the mechanical bond mechanisms to resin cements [5,8]. In this study, all specimens were air-abraded with 50 μm Al_2O_3 at 2 bar pressure, prior to simulation of a clinical try-in procedure with saliva exposure. Some authors have suggested that surface irregularities, created by sandblasting, might increase the adsorption of salivary proteins and potentially challenge the effectiveness of the cleaning methods [25]. Although it was shown that additional particle abrasion can be effective in removing saliva residues from Y-TZP ceramics [24–27,29–31,35], its use could negatively affect the long-term bond durability [36–38]. To avoid this potentially deleterious

Table 2. Results of one-way analysis of variance data of shear bond strength of experimental groups ($\alpha=0.05$).

Effect	df	Sum of squares	Mean square	F	p
Treatment	3	247.54	82.51	48.40	0.0001
Residue	56	95.46	1.70		
Total	59	343.01			

Table 3. Mean, standard deviation, minimum, maximum and confidence interval levels (95%) for shear bond strength values (MPa) recorded in each experimental group. *Means with same superscripts are not statistically different ($p>0.05$).

Experimental Groups	Mean (SD)	Minimum	Maximum	Confidence Interval	
				Lower Bound	Upper Bound
Control	12.16±1.22 ^a	9.52	14.22	11.42	12.83
WS (water-spray)	6.95±1.20 ^b	5.42	8.94	6.29	7.62
CP (cleaning paste)	11.38±1.65 ^a	8.80	13.08	10.47	12.30
AP (argon plasma)	9.17±1.06 ^c	7.93	11.02	8.57	9.76

**Fig. 2.** Type of failure mode in CP group: A, adhesive failure from ceramic surface; C, cohesive failure in resin cement. SEM: 20x magnification.**Fig. 3.** Type of failure mode in WS group: A, adhesive failure from ceramic surface. SEM: 20x magnification.**Fig. 4.** Failure mode distribution observed in experimental groups after SBS testing: adhesive failure at the interface between ceramic and luting resin; cohesive failure within the resin cement; mixed failure, a combination of both modes.

effect, the particle abrasion application was not used as a ceramic decontamination treatment in this study.

The self-adhesive resin cement used in this study contains functional monomers MDP that have phosphoric acid-functionalized groups capable of chemically reacting with the hydroxyl groups of zirconia ceramics through van der Waals forces or hydrogen bonds [4,6,8–11]. Previous studies have reported that application of an MDP-containing self-adhesive resin cement achieves a strong and reliable bond to air-abraded Y-TZP ceramics [15,16–18,34]. Given the aim of the present study, the effectiveness of cleaning methods following salivary contamination might not be clearly known if a separate ceramic primer was used before bonding. Therefore, the cement was applied to the zirconia surfaces, according to manufacturers' recommendations, without any previous primer or adhesive.

This study confirmed that contamination with saliva significantly decreases the resin bond strength to Y-TZP ceramic (6.95 MPa) compared to the control group (12.16 MPa). Water rinsing alone was not effective to eliminate the residual organic coating from the ceramic surface, which inhibits chemical bonding to zirconia. This result was in agreement with those of previous studies [24–31].

The International Academy for Adhesive Dentistry (IAAD) protocol recommends the application of particulate cleaning paste for removal of saliva or blood from Y-TZP fixed dental prostheses [35]. The universal paste used in this study is an alkaline suspension of zirconium oxide particles that removes salivary phosphate contaminants by adsorption, providing a clean surface for improved resin bonding. The CP group (11.38 MPa) showed SBS values statistically comparable to those of the uncontaminated group, which was consistent with the findings of others investigations [28–31,34]. Xie et al [11] reported that alkaline conditions positively affected formation of MDP-zirconia bonds. The cleaning agent used in the present study has high pH (13–13.5) [47], which might be responsible for improving the bond strength when used in combination with an MDP-containing self-adhesive resin cement.

Among nonabrasive cleaning methods, nonthermal plasma treatment has the additional property of surface activation. When an ionized gas atmosphere interacts with a sample, its surface can be cleaned through two different mechanisms: physical sputtering and/or chemical reaction. At the same time, the polar component of substrate is increased without affecting its morphology, thus achieving a surface better prepared for new molecular interactions [39,40]. The AP group (9.17 MPa) showed significantly higher bond strength than the WS group, but was not able to re-establish the SBS of the uncontaminated specimens. Therefore, argon plasma application was not powerful enough to remove completely the organic adhesive film layer from the air-abraded and saliva contaminated zirconia surface. Piest et al [32] evaluated the influence of contamination and plasma treatment on the

tensile bond strength of resin to zirconia ceramic. They concluded that plasma may be a valid alternative for cleaning saliva contaminated specimens, but comparing it with isopropanol ultrasonically, which has been reported to be less effective than cleaning paste used in this investigation [28,34]. The difference may be due to the plasma equipment used. In the present study, the specimens were underwent ionized argon gas atmosphere in a chairside plasma system. These devices are smaller and more user-friendly than laboratory plasma apparatus, but might not be able to produce enough energy to generate effective plasma. Güers et al [33] found that combination of isopropanol and nonthermal plasma was an effective method for cleaning saliva contaminated zirconia specimens. These results are not in accordance with the present findings. This might be due to differences in the plasma gas sources. In that study, the samples were treated with either air plasma or 1:1 argon-oxygen mixture one, whereas in the current investigation, no reactive gases were used. In inert gases-based plasmas, such as argon, the ionized and excited particles behave like molecular sandblasts, eliminating contaminants off the substrate by ion bombardment and physical ablation, but without chemically reacting with the surface [40], which could allow the presence of saliva residues after the treatment. Furthermore, in clinical practice, the more complex surface geometry of zirconia restorations may make it difficult to remove salivary contamination using this technology.

The failure modes of the study groups were investigated by stereomicroscopy and SEM. Results of failure analysis were consistent with the values obtained in the SBS tests. The control group was mostly associated with mixed failure patterns, which may support the fact that investigated self-adhesive resin cement showed an acceptable bond durability to uncontaminated Y-TZP ceramics. The application of particulate cleaning paste proved to be effective in removing saliva residues from zirconia substrates, also revealing a high percentage of mixed failures, as supported by SBS results. However, the argon plasma treatment presented a balanced distribution between adhesive and mixed failure patterns, which related to lower resin bonding due it was unable to eliminate the surface contaminants completely. The failure mode was completely adhesive for WS group, suggesting weakened bond quality, induced by the permanence of salivary remnants on the ceramic surface after the water rinsing procedure.

A standardized water storage and thermocycling regimen was used to simulate aging, thus evaluating the influence of different cleaning methods on the long-term bond strength. Although satisfactory bond strength values of resin cement to polycrystalline ceramic materials are yet to be determined for clinically successful performance, a SBS value of 10 MPa has been suggested as the clinical acceptability threshold [7]. After 10,000 thermocycles, none of the study specimens debonded spontaneously, but only the uncontaminated and CP group samples maintained SBS values greater than that limit. Although short-term resin bond strength to zirconia was not investigated in this investigation, the results obtained after artificial aging were in accordance with the findings of previous studies, which reported long-term water storage and thermocycling weaken the bond integrity [18,24,34,38]. Yang et al [18] showed that MDP-containing self-adhesive resin cements were not completely hydrolytically stable, since their bond durability to zirconia was compromised during artificial aging. These cements are more hydrophilic due to the high content of acid-functionalized monomers; as a result, they show higher water sorption than conventional resin cements and, consequently, may be more prone to hydrolytic degradation via hydrolysis of the Zr-O-P bond [48,49].

There were some limitations in the present study. The bond strength was evaluated by traditional shear tests. Although this methodology has been frequently criticized for the development of nonhomogeneous stress distributions in the bonded interface, the SBS test are not technique sensitive and still useful in assessing the effectiveness of surface conditioning treatments [28]. Another limitation of the investigation was that only salivary contamination was considered, obviating blood and silicone try-in pastes as possible contaminants. Some aspects such as the use of only one self-adhesive resin cement and the absence of a short-term evaluation are also limitations. These and other aspects, such as the mutual effect of MDP between primers and self-adhesive cements, as well as the use of alternative cleaning pastes, should be addressed in future

investigations. Moreover, long-term clinical studies are needed to verify the real effect of these findings on resin bonding to saliva contaminated zirconia.

5. Conclusion

The present study confirms that cleaning of the saliva contaminated ceramic surface before adhesive cementation is an indispensable step in order to achieve a durable bond. The cleaning paste application was the most effective method in removing saliva contamination and enhancing the bond strength of MDP-containing self-adhesive resin cement to Y-TZP ceramic. However, the argon plasma treatment was not able to restore the SBS to the same level as uncontaminated zirconia.

Conflict of interest statement

None of the authors have conflicts of interest to declare.

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