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Evaluation of short- and long-term bond strength of zirconia after different surface treatments

Avaliação da resistência de adesão de curto e longo prazo de zircônia após diferentes tratamentos de superfície

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ABSTRACT

Objective: The aim of the study was to evaluate the short and long-term effects of different surface treatments on the bond strengths of zirconia. **Material and Methods:** 225 blocks of sintered zirconia samples (4 x 4 x 3 mm) were divided into five groups and subjected to different surface treatments: control group (without surface treatment), alumina group (sandblasting [25-μm-aluminum-oxide]), alumina+Ambar Universal-APS (AU) group, CoJet group (silica-coated [30-μm silica-modified aluminum particles]), and CoJet+AU group. Subsequently, zirconia samples were cemented against resin samples (total dimensions: 8x8x6mm) and assigned to three storage conditions: dry, humid (artificial saliva at 37°C for 30-days) or thermocycling [100.000-cycles] (n=15 per group). The microtensile bond strength (μTBS) was determined using a universal testing machine. The failure modes were observed and analyzed using a stereomicroscope. Normality tests, descriptive statistics, and two-way ANOVA, followed by post-hoc comparisons, were performed to evaluate the effect of surface treatments and storage conditions on μTBS (α=0.05). **Results:** μTBS was influenced by surface treatment in the short and long-term ($P<0.0001$). The highest values were found in CoJet+AU in dry (33.51 ±2.48 MPa), humid (32.87 ±2.68 MPa) and thermocycling (21.37 ±1.68 MPa) storage conditions compared with others. Interestingly, no significant differences in μTBS were found among alum +AU and CoJet alone under any of the three storage conditions. Adhesive failure increased in all groups after thermocycling, but CoJet+AU had the lowest values of adhesive failure compared with others. **Conclusion:** The combination of CoJet and Ambar universal as a surface treatment for zirconia specimens provides significantly higher short and long-term bond strengths of adhesive cementation.

KEYWORDS

Adhesives; CoJet; MDP; Sandblasting; Zirconia.

RESUMO

Objetivo: O objetivo do estudo foi avaliar os efeitos de curto e longo prazo de diferentes tratamentos de superfície na resistência de adesão da zircônia. **Material e Métodos:** 225 blocos de amostras de zircônia sinterizada (4 x 4 x 3 mm) foram divididos em cinco grupos e submetidos a diferentes tratamentos de superfície: grupo controle (sem tratamento de superfície), grupo de alumina (jateamento de 25 μm de óxido de alumínio), grupo alumina+Ambar Universal-APS (AU), grupo CoJet (partículas de alumínio modificadas por sílica de 30 μm), e grupo CoJet+AU. Posteriormente, as amostras de zircônia foram cimentadas em amostras de resina (dimensões totais: 8x8x6mm) e designadas para três condições de armazenamento: seco, úmido (saliva artificial a 37°C por 30 dias) ou ciclagem térmica (100.000 ciclos) (n=15 por grupo). A resistência de adesão de microtensão (μTBS) foi determinada usando uma máquina de teste universal. Os modos de falha foram observados e analisados usando um estereomicroscópio. Testes de normalidade, estatísticas descritivas e ANOVA de duas vias, seguidas de comparações pos-hoc, foram realizados para avaliar o efeito dos tratamentos de superfície e das condições de armazenamento na μTBS (α=0.05). **Resultados:** A μTBS foi influenciada pelo tratamento de superfície a curto e longo prazo ($P<0.0001$). Os valores mais altos foram encontrados em CoJet+AU nas condições de armazenamento a seco (33.51 ±2.48 MPa), úmido (32.87 ±2.68 MPa) e ciclagem térmica (21.37 ±1.68 MPa) em comparação com os outros. Curiosamente, não foram encontradas diferenças significativas na μTBS entre alum +AU e CoJet sozinho em nenhuma das três condições de armazenamento. A falha adesiva aumentou em todos os grupos após a ciclagem térmica, mas CoJet+AU teve os valores mais baixos de falha adesiva em comparação com os outros. **Conclusão:** A combinação de CoJet e Ambar Universal como tratamento de superfície para espécimes de zircônia proporciona resistências de adesão significativamente mais altas a curto e longo prazo para cimentação adesiva.

PALAVRAS-CHAVE

Adesivos; CoJet; MDP; Jateamento-de-areia; Zircônia.

INTRODUCTION

New ceramics have been developed to meet the functional and aesthetic requirements of dentistry [1]. Its main characteristics include translucency, biocompatibility, high mechanical resistance, and color mimetics to obtain high aesthetic results [2]. Zirconium oxide ceramics (ZrO_2, 3rd generation) have been widely used in prosthetic dentistry, and the clinical success of restorations depends not only on esthetic or functional results but also on bond durability between dental tissues and prosthetic substrates [3-6].

Yttrium-stabilized tetragonal zirconia polycrystals (Y-TZP) are widely used in aesthetic dentistry because of their excellent mechanical and esthetic properties owing to the stabilization of the tetragonal phase [7,8]. Its mechanical properties are comparable to those of metals, but the naturality of color increases its election [9]. Y-TZP crowns can be cemented by conventional or resin cements, and the latter reports the highest bond strength values to teeth structures [8,10]; however, the authors reported a high level of debonding of Y-TZP crowns [11-14].

To improve the adhesion rates of non-silicate ceramics such as Y-TZP, many surface treatments have been evaluated [15], including solutions composed of multiple acids, such as phosphoric acid (H_3PO_4) [16] or hydrofluoric acid (HF) [17] with poor results because of the absence of a glass phase in its structure [7].

Airborne-particle abrasion (APA) as surface treatment is an appropriate method for increasing the surface energy and wettability of substrates to improve their bond strength [18]. The generated surface roughness helps create an active surface with micromechanical gearing into the connection interface [19-21]. APA treatment with aluminum oxide could increase the bond strength in Y-TZP crowns, although the results are contradictory [22-25].

Chemical surface treatments can also increase bond strength during crowns cementation [26]. Few studies have shown that a tribochemical silica-coated (TSC) [27-30] or a functional monomer of 10-methacrylixydecyl dihydrogen phosphate (MDP) [31] can increase the bond strength between cement and ceramic crowns. New zirconia cementation protocols use self-adhesive resin cements and new universal adhesives that contain MDP, producing Y-TZP crowns with stable and durable bond strength [32-34].

During the consumption of food and liquids, dental materials undergo thermal cycling [35]. To simulate temperature variations in the oral cavity, thermal cycling-controlled water baths have been used in in vitro studies [36]. It is currently reported the use of thermal cycles between 5°C and 55°C to simulate the aging of dental materials [37] and 100.000 cycles is equivalent to 10 years of in vivo function, which is considered a long-term time period for dental material evaluations [38].

The effect of the combination of sandblasting and universal adhesives containing MDP on Y-TZP samples and the long-term bond strength after adhesive cementation has not been fully elucidated. The aim of this in vitro study was to evaluate the effects of different surface treatment methods in combination with or without MDP monomers on the microtensile bond strength (μTBS) between zirconia samples and resin blocks in different storage environments during short or long-term in vitro aging. The first null hypothesis of the present study posited that the μTBS between zirconia-resin blocks would not be significantly affected by the combination of surface treatment and the use of an MDP-containing adhesive, regardless of the storage conditions or time. The second null hypothesis posited that the in vitro aging duration (short- vs. long-term) would not significantly influence the μTBS between zirconia-resin blocks, regardless of the combination of surface treatment and the use of an MDP-containing adhesive.

MATERIAL AND METHODS

Samples

A total of 225 zirconia samples (4 × 4 × 3 mm) were cut from pre-sintered green zirconia blocks [3rd generation]; (Cercon Zirconia, Degodent, Harnau, Germany) using a diamond cutting saw (Isomet 1000; Buehler, Lake Bluff, IL, USA). Specimen surfaces were then sequentially polished with 600-1200-2000-2400 grit silicon carbide abrasives (3M ESPE, St. Paul, MN, USA). After polishing, all samples were sintered at 1,350°C for 2 h (Heat DOU; Degodent, Harnau, Germany). The samples were cleaned ultrasonically in an acetone solution for 5 min and then air-dried. A total of 225 composite resin samples (Opallis [FGB, Brazil]) (4 mm × 4 mm × 3 mm) were fabricated using a custom silicone mold. Two composite resin layers (1.5 mm) were applied to the custom mold and each layer was light-polymerized (Demi Ultra; Kerr) separately for 20 s.

Surface treatments

Zirconia samples were randomly divided and assigned to 5 different surface treatments: (1) Control group: no surface treatment; (2) Alumina group (Alum): aluminum oxide airborne-particle abrasion (25 μm particle size, WA25, Heraeus Kulzer, Hanau, Germany) was sandblasted with a pressure of 0.45 MPa (15 s/cm2) at a distance of 10 mm; and (3) Alumina + AU group (Alum + AU): alumina airborne-particle abrasion and universal adhesive "Ambar APS" (FGM, Brazil) application; (4) CoJet group: silica-coated airborne-particle abrasion (30 μm particle size, CoJet, 3M ESPE) blasted onto the bonding surface of zirconia samples with a pressure of 0.45 MPa (15 s/cm^2) and a distance of 10 mm; (5) CoJet + AU group: silica-coated airborne-particle abrasion and universal adhesive "Ambar APS" (FGM, Brazil) application.

Bonding procedure

The zirconia and resin samples were bonded with resin cement "Allcem dual" (FGM, Brazil) after surface treatments under a constant load of 1 kg/F to standardize the exerted pressure. Excess resin cement was removed using foam pellets, and glycerin was applied around the bonding margin to prevent the formation of an oxygen inhibition layer. All cemented samples were light-polymerized (Demi Ultra; Kerr) from four sides for 20 s each.

Environment storage

The experimental groups were then divided into three subgroups: (1) dry environment, (2) storage in artificial saliva (ISO/TR10271) at 37°C for 30 days, and (3) subjected to 100.000 thermal cycles in artificial saliva (5°C and 55°C).

Microtensile bond test

All the samples were then mounted in acrylic tubes, and μTBS (MPa) [39] was evaluated using a universal testing machine (T-6102K; Bisco) at a crosshead speed of 1.0 mm/min until failure. Cross-sections of the ceramic samples were analyzed using a microscope (Leica DM500; Leica Microsystems) at ×40 magnification to assess the fractured interfaces. Failure conditions were classified into three types: adhesive (failure at the bonding interface), cohesive (failure in zirconia, resin, or resin cement), and mixed (adhesive and cohesive failures).

Statistical analysis was performed using the GraphPad Prism software (version 9.0) for Windows 10. μTBS values were analyzed using 2-way ANOVA followed by post-hoc pairwise comparisons to evaluate the effects of surface treatments, storage conditions, and their interactions. Tukey's test was used for multiple comparisons.

RESULTS

The mean μTBS values are presented in Table I. Surface treatment of zirconia samples (F [4, 210] = 436.1, $P<0.0001$) and storage conditions (F [2, 210] = 475.5, $P<0.0001$)

Table I - Mean ± standard deviation of μTBS (MPa) after surface treatments in different storage conditions

Storage conditions	Control	Alum	Alum + AU	CoJet	CoJet + AU
Dry	12.97 ±2.61	22.63 ±1.86 ^{a}	25.48 ±1.84 ^{b}	26.61 ±2.50 ^{b}	33.51 ±2.47 ^{c}
Humid	12.36 ±2.93	22.10 ±3.05 ^{a}	24.83 ±2.40 ^{b}	26.19 ±1.99 ^{b}	32.87 ±2.67 ^{c}
Thermocycling	6.19 ±1.13	12.11 ±1.68 ^{a}	16.11 ±1.60 ^{b}	16.13 ±1.50 ^{b}	21.37 ±1.68 ^{c}

^{a}<0.0001 compared with control. ^{b}<0.0001 compared with control / Alum. ^{c}<0.0001 compared with control / Alum / CoJet.

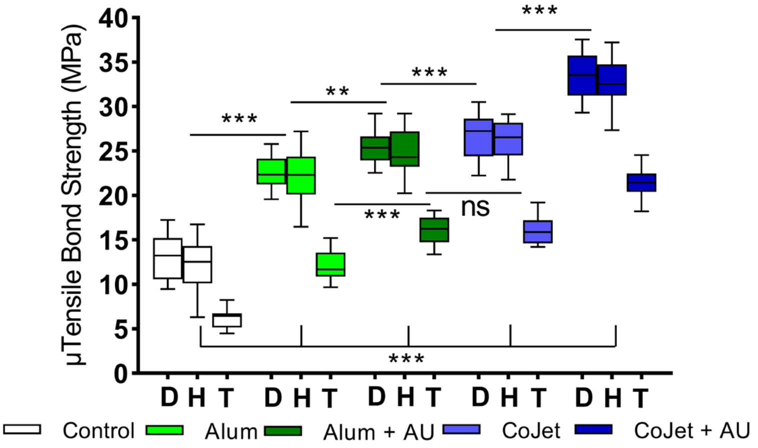

Figure 1 - Microtensile bond strength of samples after different surface treatments in three storage conditions. D: dry condition, H: humid condition and T: thermocycling. Groups: Control, Alum (alumina), Alum + AU (alumina + Ambar universal), CoJet and CoJet + AU (Ambar universal). ns: not significant, ** P<0.01 and ***P<0.0001.

significantly affected μTBS. Regarding the interaction between variables, the two variables showed a significant difference (F [8, 210] = 4.102, P = 0.0001).

The bond strength values in the dry condition among the experimental groups were significantly different from those in the control group (P<0.0001). The combination of CoJet + AU demonstrated the greatest mean values of μTBS (33.51 ±2.47 MPa) compared with CoJet (26.61 ±2.50 MPa), Alum + AU (25.48 ±1.84 MPa), Alum (22.63 ±1.86 MPa) and control (12.97 ±2.61 MPa).

When the zirconia samples were stored in humid conditions for 30 days (37°C), all experimental groups showed significant differences compared to the control group (P<0.0001). CoJet + AU obtained the higher mean values of μTBS (32.87 ±2.67 MPa) compared with CoJet (26.19 ±1.99 MPa), Alum + AU (24.83 ±2.40 MPa), Alum (22.10 ±3.05 MPa) and control (12.36 ±2.93 MPa) (Figure 1).

For the zirconia samples exposed to thermocycling (100.000), even though all groups had reduced μTBS values, all experimental groups showed significant differences compared to the control group (P<0.0001). CoJet + AU obtained the higher mean values (21.37 ±1.68 MPa) compared with CoJet (16.13 ±1.50 MPa), Alum + AU (16.11 ±1.60 MPa), Alumina (12.11 ±1.68 MPa) and control (6.19 ±1.13). These results show that the combination of CoJet + AU yielded the highest μTBS values under all storage conditions. These results showed that the most effective surface treatment for zirconia under all conditions was the combination of CoJet + AU (Figure 1).

Tukey's multiple comparison test showed significant differences between CoJet + AU and all experimental groups in all storage environments (P<0.0001). Interestingly, significant differences were observed between CoJet and Alum + AU under dry conditions (P=0.0001), but no differences were reported between the two groups under humid conditions (P=0.9315) or after thermocycling (P>0.9999). Significant differences were observed between Alum + AU and Alum under dry conditions (P=0.0043), humid conditions (P=0.0073), and after thermocycling (P<0.0001) (Figure 1). These results showed that Ambar Universal increased μTBS after sandblasting treatments under all storage conditions.

The correlation matrix showed a significant relationship among all surface treatments tested (r=0.9993, P=0.0233 for alum, r=0.9998, P=0.0119 for Alum + AU, r=0.9990, P=0.0290 for CoJet, and r=0.9994, P=0.0218 for CoJet + AU) in the increase of μTBS in all storage conditions compared with the control group. Interestingly, Ambar Universal showed a significant relationship with the increase in μTBS in all storage conditions in sandblasting groups (CoJet AU vs. CoJet: r=0.9999, P=0.0073 and Alum + AU vs. Alum: r=0.9998, P=0.0114) (Figure 2).

The failure mode results are presented in Table II. Surface treatment of the zirconia samples (F [4, 210] = 592.8, P<0.0001) and storage conditions (F [2, 210] = 766.4, P<0.0001) significantly affected the failure mode. Regarding the interaction between variables, the two variables showed a significant difference (F [8, 210] = 11.01, P< 0.0001). No cohesive failures were observed after the μTBS testing.

The percentage of failure mode values in the control group was significantly different from those in the experimental groups under all storage conditions (P<0.0001). Experimental groups reported significant differences in adhesive failures between them under all storage conditions (P<0.0001), except between Alum + AU and CoJet (dry P=0.6369, humid P=0.289, and thermocycling P=0.9845).

Under dry conditions, the combination of CoJet + AU demonstrated the lowest mean values of adhesive failures (9.27% of adhesive vs. 90.73% of mixed) compared with CoJet (20.80% of adhesive vs. 79.20% of mixed), Alum + AU (24.13% of adhesive vs. 75.87% of mixed), Alum (49.47% of adhesive vs. 50.53% of mixed), and control (75.93% of adhesive vs. 24.07% of mixed) (Figure 3a).

Under humid conditions, the combination of CoJet + AU showed the lowest mean values of adhesive failures (11.27% of adhesive vs. 88.73% of mixed) compared with CoJet (26.33% of adhesive vs. 73.67% of mixed), Alum + AU (31.00% of adhesive vs. 69.00% of mixed), Alum (55.00% of adhesive vs. 45.00% of mixed), and control (76.73% of adhesive vs. 23.27% of mixed) (Figure 3b).

Finally, after thermocycling, CoJet + AU surface treatment showed the lowest mean values of adhesive failures (45.80% of adhesive vs. 54.20% of mixed) compared with CoJet (70.47% of adhesive vs. 29.53% of mixed), Alum + AU (71.73% of adhesive vs. 28.27% of mixed), Alum (83.33% of adhesive vs. 16.67%

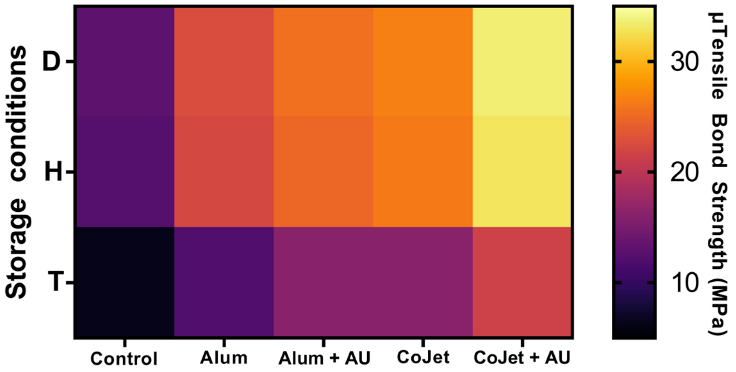

Figure 2 - Correlation matrix of microtensile bond strength (MPa) and Storage conditions of samples after different surface treatments. D: dry condition, H: humid condition and T: thermocycling. Groups: Control, Alum (alumina), Alum + AU (alumina + Ambar universal), CoJet and CoJet + AU (Ambar universal).

Table II - Percentage (%) of failure mode after surface treatments in different storage conditions

Storage conditions	Control	Alum	Alum + AU	CoJet	CoJet + AU
	Adhe / Mix	Adhe / Mix	Adhe / Mix	Adhe / Mix	Adhe / Mix
Dry	75.93 / 24.07	49.47 / 50.53	24.13 / 75.87	20.80 / 79.20	9.27 / 90.73
Humid	76.73 / 23.27	55.00 / 45.00	31.00 / 69.00	26.33 / 73.67	11.27 / 88.73
Thermocycling	100 / 0	83.33 / 16.67	71.73 / 28.27	70.47 / 29.53	45.80 / 54.20

No cohesive failures were showed after μTBS testing. Failure mode: Adhe: Adhesive. Mix: Mixed (adhesive and cohesive).

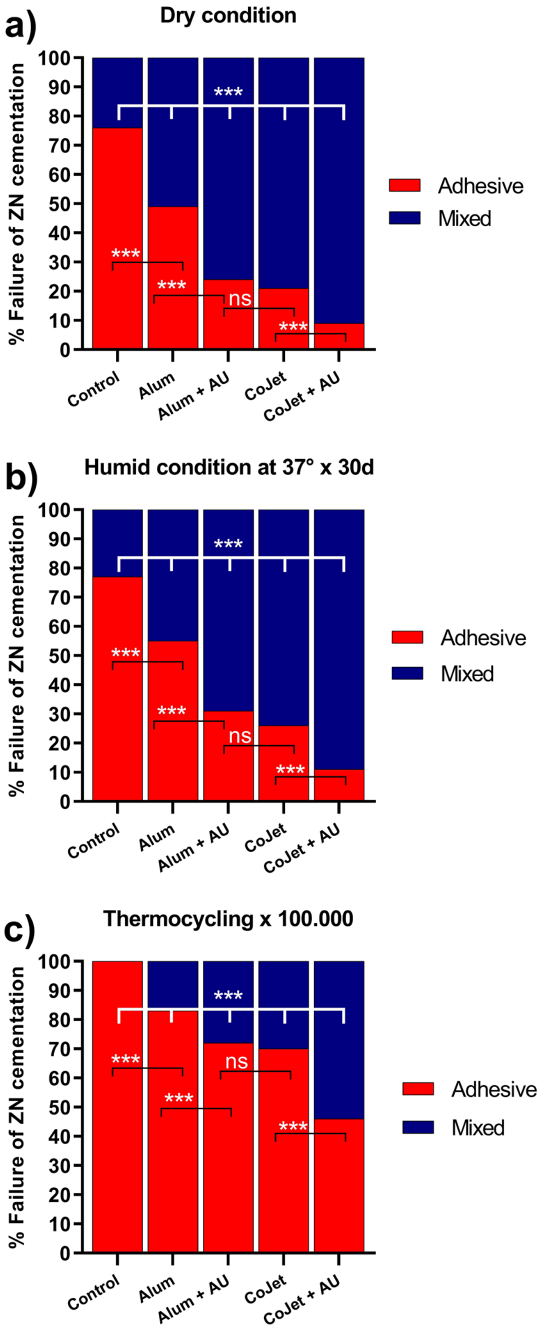

Figure 3 - Failure modes percentage after different surface treatments in three storage conditions. a) Dry condition. b) Humid condition. c) Thermocycling. Groups: Control, Alum (alumina), Alum + AU (alumina + Ambar universal), CoJet and CoJet + AU (Ambar universal). ns: not significant and ***P<0.0001.

of mixed), and control (100% adhesive vs. 0% mixed) (Figure 3c). These results showed that Ambar universal decrease the percentage of adhesive (Figure 4a) and mixed (Figure 4b) failures compared with sandblasting alone after in vitro “intra-oral aging,” suggesting that the combination of sandblasting of CoJet or Alum + AU increase the “adhesive” properties during zirconia cementation.

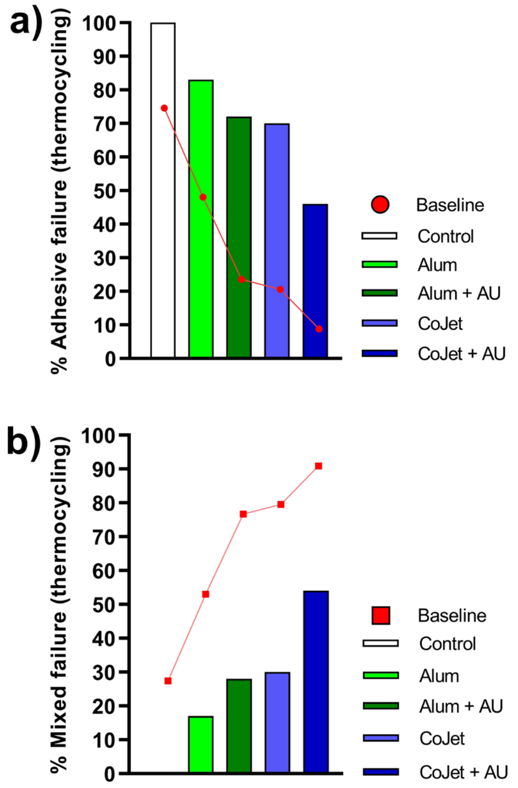

Figure 4 - Comparison of failure modes percentage in dry condition (baseline) vs thermocycling (bars). a) Adhesive failure. b) Mixed failure. Red forms: baseline during adhesive or mixed failures. Groups: Control [white], Alum (alumina) [light green], Alum + AU (alumina + Ambar universal) [dark green], CoJet [light blue] and CoJet + AU (Ambar universal) [dark blue].

DISCUSSION

Zirconia, a commonly utilized aesthetic material in prosthetic dentistry, has a notable limitation owing to its lack of a glass phase. This absence prevents hydrofluoric acid etching, thereby reducing the surface energy and wettability of the material, which are crucial factors for enhancing the bonding strength during cementation [8]. Consequently, achieving zirconia restorations with high bond strength can be particularly challenging owing to their weaker bond interface with tooth substrates. However, studies have shown improvements in bond strength through surface modifications of zirconia when adhesive cements are employed [10,32].

Nanotechnology has also emerged as a promising field for enhancing the properties of dental materials [40]. The use of nanoscale fillers in dental adhesives could enhance mechanical properties, increase the surface area for bonding, and improve resistance to wear and degradation [41]. Nanoscale modifications of zirconia, such as nanoparticle coated or the creation of nanotextured surfaces, could also potentially improve the adhesion of zirconia with resin cements [42].

In our study, we observed that all tested surface treatments elevated μTBS in comparison to the control group, and a decrease in μTBS was observed after subjecting the samples to humid conditions and thermocycling [43,44]. This decrease is generally attributed to the different thermal expansion coefficients of the various materials involved, such as adhesives, resin cement, and zirconia. The thermal stresses induced by thermocycling can lead to the formation of micro-cracks and degradation at the interfaces, hence reducing bond strength [45]. However, the combination of CoJet + Ambar Universal showed the highest bond strength in the short and long-term of in vitro aging compared to the other groups.

It has been reported that materials with silica-rich surfaces exhibit enhanced adhesion properties between the hydroxyl group on the silica surface and a silane coupling agent [46]. TSC or 'silicatization' treatment has been shown to increase μTBS due to the creation of both micromechanical and chemical modifications on the zirconia surface [47,48]. Further studies have reported that chemical conditioning (siloxane network) is more important than micromechanical modifications during resin-ceramic cementation [49,50]. Despite these findings, it has been reported that the combination of surface treatment with aluminum oxide and silane, while increasing the wettability of resin cements and bond strength relative to controls, is not expected to result in any chemical reactions [51].

The process of TSC sandblasting is particularly intriguing, as it transfers mechanical energy in the form of kinetic energy to the treated surface. This process results in a local temperature increase owing to the kinetic energy generated when the TSC particles strike the zirconia. The resultant thermal energy aids in the melting of silica particles, leading to chemical conditioning of the zirconia surface [52]. Moreover, the sandblasting pressure of 0.28 MPa (indicated by the manufacturer) was not sufficient to obtain a homogeneous TSC layer [52]. Furthermore, García-de-Albeniz et al. (2023) [53] reported a direct relationship between the pressure of airborne particle abrasion, the amount of silica layer over zirconia, smaller particle size during sandblasting procedures, and an increase in bond strength after cementation [54,55], suggesting that pressure and particle size are critical for achieving higher bond strength results, as well as the type of surface treatment.

Our results showed that Ambar Universal increased the μTBS of the zirconia samples after sandblasting. Moreover, the combination of CoJet and Ambar Universal obtained the highest μTBS results in the long-term (10 years of intraoral aging), suggesting a predictable protocol for zirconia adhesive cementation. Remarkably, the Alumina and Ambar Universal combination yielded results similar to those of CoJet alone in humid conditions and post-thermocycling aging. This implies another viable alternative for surface treatment in the absence of silicatisation.

MDP-containing silane agents enhance the bond strength of zirconia samples when resin cements are used through the phosphate ester group of the MDP [56]. However, these agents form weak covalent bridges directly over zirconia [57]. Nagaoka et al. (2019) [52] reported that the combination of TSC treatment and a universal primer containing MDP creates a polymer network among silica, aluminum oxide, and methacrylate groups of adhesive agents, enabling adhesive polymerization between the resin cement and methacrylate end over pretreated zirconia. Several studies have reported that MDP-containing adhesives achieve higher bond strengths to zirconia frameworks through chemical reactions of interfacial interactions, such as van der Waals forces or hydrogen bonds [58]. Thus, the application of MDP-containing adhesives to TSC-pretreated zirconia can generate a stable and durable bond strength between zirconia and resin cements.

Humid storage conditions and thermocycling are frequently used to simulate the aging of adhesive-bond interfaces. The intervals of temperatures from 5 °C to 55 °C for thermal cycles are described in accordance with the ISO TS 11405 technical specification for testing the adhesion to tooth structure [59]. Further studies have reported a decrease in bond strength after artificial aging (water storage or thermocycling) [35,37,38] and a strong degradation of the zirconia-cement interface after water storage at 37°C for 7 days [60].

Different media have been used for in vitro intraoral aging simulations (including water, ethanol, or sodium hypochlorite dilutions) to degrade bonded interfaces. However, these media lack the enzymatic activity present in saliva. Artificial solutions replicate the enzymatic features of human saliva, mimicking the in vivo biochemical degradation of an adhesive interfaces. Moreover, recent studies have suggested the use of mechanical loading in addition to thermocycling, to replicate the oral environment more accurately [61,62]. This could involve simulating biting forces, which might affect the bond strength of restorations. Additionally, long-term clinical trials are crucial for confirming the findings of in vitro studies.

Interestingly, our study showed that the combination of CoJet and Ambar Universal resulted in the lowest values of adhesive failure after short- and long-term intraoral aging using artificial saliva as a liquid medium. These findings confirm a predictable protocol for zirconia adhesive cementation against enzymatic degradation during intraoral performance.

CONCLUSIONS

Based on the findings and limitations of this in vitro study, the following conclusions were drawn:

1. The combination of TSC (CoJet) and MDP-containing adhesives (Ambar) as a surface treatment for zirconia specimens provides significantly higher short- and long-term bond strengths when adhesive cementation is used, compared with silicatization alone, aluminum oxide with or without universal adhesive, or without surface treatment.
2. The combination of aluminum oxide sandblasting and universal and MDP-containing adhesives (Ambar) as a surface treatment for zirconia specimens provides similar results to TSC alone on the bond strength after adhesive cementation, resulting in an adequate alternative when silicatization is not possible.

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Author’s Contributions

NPP: Conceptualization, Methodology, Supervision, Formal Analysis, Writing – Original Draft Preparation, Writing – Review & Editing. PLA: Conceptualization, Writing – Original Draft Preparation, Visualization. MD: Investigation, Resources, Writing – Review & Editing. LA: Investigation, Resources, Writing – Review & Editing. PR: Conceptualization, Supervision, Visualization, Writing – Review & Editing.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of University Viña del Mar. The approval code for this study is #56-23.

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