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THE INFLUENCE OF DIFFERENT SURFACE TREATMENTS ON BOND STRENGTH OF CAD/CAM FABRICATED CERAMIC RESTORATIONS

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ABSTRACT

Objectives: This study aimed to assess the effect of various surface treatments on the bond strength of ceramic restorations constructed with CAD/CAM technology.

Materials and methods: A total of sixty ceramic discs were manufactured using CAD/CAM technology with dimensions (8×3mm). Discs were categorized into two main groups (n=30) based on type of ceramic used (Zirconia (Z) and Vita enamic (V)). Each group was subdivided into three subgroups depending on aluminum oxide particles size used for sandblasting (40, 80 and 110 µm) then Monobond® N primer was applied to all discs. Sixty composite resin discs (4 mm×3 mm) were fabricated and adhered to ceramic discs using adhesive resin cement (Multilink®N). All specimens were kept for three months in a water bath at 37°C, then 3000 thermal cycles (5–55°C). Using a universal testing machine, the shear bond strength was recorded. To examine the failure mode, a scanning electron microscope (SEM) was used. The data were tabulated and statistically analyzed.

Results: The results of this study revealed statically significant differences in SBS between most of groups (P<0.05). V110 µm group demonstrated the highest SBS, followed by the V80 µm group, and there was a significant difference between both groups (p = 0.045). There was a statistically significant difference between Z40 µm group compared to the other two groups (Z80 and Z110 µm). The lowest mean SBS value was observed for the Z40 group.

Conclusions: Different size of aluminum oxide particles affected the SBS to CAD/CAM fabricated ceramic materials.

KEYWORDS: Machinable ceramics, Surface treatment, Ceramic primer, Resin cements, Bond strength.

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INTRODUCTION

All age groups in today's society are becoming more conscious of esthetic standards. As a result, esthetic concerns must be taken into account when providing dental care. Therefore, metal-free techniques are currently popular in dentistry, and their use has been growing significantly in recent years.[1, 2]

High wear resistance, superior hardness, biocompatibility, and susceptibility to tensile fracture are the features that most ceramics exhibit.[3]

CAD/CAM technology is used in the current era of restorative dentistry to provide rapid and precise results. This chairside service also enables better, faster, and more accurate quality of the product. [4, 5] It is expected that there will be fewer material failures during clinical applications and the manufacturing process.[6] CAD/CAM blocks are more reliable because they have fewer defects than hand-built materials. [7, 8]

Moreover, CAD/CAM systems offer several benefits, such as reduced production costs and standardized dental restoration manufacturing procedures.[9] In brief, digital scanning offers a quicker and easier therapeutic modality compared to traditional methods. Furthermore, having milling machines on site permits patients to receive their definitive restoration on the same visit, overcoming the need for a temporary restoration that requires a lot of time for construction and fitting. As a result of the use of digital technologies (DT), CAD/CAM restoration quality is superior because measurements and fabrications are precise. [10]

Several products can be used in CAD/CAM restorative materials called blocks. These include aluminium oxide, yttrium tetragonal zirconia poly-crystals, leucite-reinforced glass ceramics, feld-spathic glass ceramics, lithium disilicate, and com-posite blocks. Currently, ceramics and composites are the two main categories into which nonmetal CAD/CAM restoratives have fallen. [11]

Numerous novel esthetic materials have been progressively incorporated into dentistry as a result of advancements in material science and the growing acceptance of digital technology. These materials have superior mechanical qualities, such as strength, fatigue resistance, and water absorption resistance, in addition to their identified esthetic qualities. Because of its superior mechanical qualities and biocompatibility, zirconia is the most widely used new esthetic material among them. [12] Zirconia has been extensively utilized in dental prosthetics, including implants, bridges, and crowns, over the last ten years. [13]

Indirect composite restorations are softer, more flexible, and easy to finish and polish than ceramic restorations. In addition, even with their high wear, they are not as aggressive on the opposing dental tissues and are therefore better for add-on adjustments.[14] Other than, restorations made with ceramic have more esthetically pleasing qualities than composite ones, and ceramic materials exhibit greater resistance to wear, discoloration, and biocompatibility. Nevertheless, their brittleness can result in excessive wear on the opposing dentition and fractures due to the development of defects or flaws in the intaglio surfaces. [15]

A recently produced material is ceramic network infiltrated with polymers.[14] This novel material, also referred to as hybrid ceramic, is made up of a network of acrylate polymers (14%), which reinforces the majority of the ceramic network (86%). There is uniform mixing between these two networks. [16] The ceramic component of the actually accessible product (Vita Enamic; VITA Zahnfabrik, Bad Sackingen, Germany) is mixed with polymers such as urethane dimethacrylate (UDMA) and others, resulting in a fine-structure feldspar matrix enhanced with aluminium oxide. [17] It is anticipated that this material has numerous benefits over ceramics, such as reduced stiffness, brittleness, and hardness; increased flexibility; and improved machinability and fracture toughness. [14]

One of the biggest challenges presently affecting zirconia-based dental restorations is surface preparation for resin-cement bonding. Zirconia, in contrast to feldspathic porcelain and glass ceramics, is entirely composed of the crystalline phase and lacks a glassy matrix, making it resistant to etching by hydrofluoric acid. In order to improve the zirconia-resin bonding, a different technique than acid etching must be used to create microstructures for micromechanical adhesion or chemical bonding. Numerous researchers have looked into various techniques to improve the bonding between zirconia and resin and to create surface roughness on zirconia.[18-20]

As a result, several types of resin cement, primers, and surface treatments for zirconia have been tested. Moreover, retention is necessary both chemically and mechanically to form a strong bond between a resin and ceramic. Because of this, some surface treatments, including sandblasting, sandblasting with primers, tribochemical silica coating, and laser irradiation, have been suggested for resin bonding to zirconia. [21]

Sandblasting creates a rough surface for cement, which can effectively increase the bonding strength between ceramic materials. The adhesion strength of dental ceramics to resins is enhanced by the use of primers containing 10-MDP (10-methacryloyloxyidecyl-dihydrogenphosphate), which is often applied after alumina sandblasting. This leads to the chemical bonding of 10-MDP and yttrium-stabilized zirconium oxide blocks (Y-TZP), maintaining a straightforward procedure for ceramic substrates to produce excellent bonding using adhesive resin cement.[22-24]

Restorations are susceptible to a range of mechanical and thermal stresses as a result of the intraoral masticatory forces in the mouth. A variety of artificial ageing techniques, including heat cycling and long-term water storage can mimic intraoral circumstances. They are essential in determining how long-lasting a bond is formed between ceramics and resin cements. [25]

Even though the bonding effectiveness between the luting agent and machinable dental ceramics using different particle sizes of Al_2O_3 followed by primer application has not been well researched. There is a lack of scientific data regarding the bonding behavior of various surface enhancements applied to the new CAD/CAM materials. Thus, the hypothesis of this laboratory work is that the bond strength of CAD/CAM-fabricated ceramics was not affected by different surface treatments using various Al_2O_3 particle sizes, followed by primer coating.

Study Design

This laboratory research used various alumina particle sizes to assess the effects of surface treatments on the bonding strength of ceramic restorations manufactured using CAD/CAM technology. The study was carried out following approval from the ethics committee (A01012023 FP).

MATERIALS AND METHODS

The materials used in this study in addition to their basic compositions are listed in **(Table 1).**

Methods

1. Ceramic disc fabrication:

A total of sixty ceramic discs were fabricated for this in-vitro research and divided into two main groups (n = 30) based on the type of machinable ceramic used. A CAD/CAM device (Ceramill mikro, Amann Girbach, Germany) was used to mill zirconia (IPS e.max ZirCAD, A3.5 Ivoclar Vivadent, Liechtenstein) and hybrid ceramic Vitaenamic (VITA ENAMIC blocks 3M2-HT-EM-14, VITA-Zahnfabrik, Bad Säckingen, Germany). Using alumina particle size, each main group of ceramic discs (n = 30) was further subdivided into three subgroups (n = 10). In the final analysis, six groups were involved in this study.

TABLE (1) Description of materials utilized in the study.

Materials	Commercial Name	Batch number	Composition	Manufacturer
Zirconia	IPS e.max® ZirCAD	W89510	ZrO_2 (87-95%) Y_2O_3 (4-6%) HFO_2 (1-5%) Al_2O_3 (0.1-1%)	Ivoclar Vivadent AG
Vita Enamic.	Polymer infiltrated ceramics VITA ENAMIC blocks 3M2-HT-EM-14	36660	Polymer infiltrated ceramic, SiO2 (58–63), Al2O3 (20–23), Na2O (9–11), K2O (4–6), B2O3 (0.5–2), ZrO2 (<1), KaO (<1)	VITA Zahnfabrik, Spitaglasses 3, D-79713 Bad Säckingen, Germany
Composite resin	REFLECTYS Universal restorative composite	DF2D81A2	Barium aluminosilicate ,Triethyleneglycol dimethacrylate ,Fumed silica ,The percentage by weight of total inorganic filler is ca.80% , Bis-GMA	ITENA® Villepinta- FRANCE
Ceramic Primer	Monobond ®N	Z03CXK	Ethanol, trimethoxysilylpropyl methacrylate, 10-MDP. disulfide acrylate silane, methacrylated phosphoric acid ester, sulphide methacrylate	Ivoclar Vivadent AG Liechtenstein
Adhesive resin cement	Multilink ®N	Z044J4	Matrix: dimethacrylates and HEMA Inorganic fillers: barium glass, ytterbium trifluoride and spheroid mixed oxide	Ivoclar Vivadent AG Liechtenstein
40 μm Al_2O_3 for sandblasting	Aluminum oxide 40 micron tan	1Bc92018	99.7% aluminum oxide	Moka dent, Egypt
80 μm Al_2O_3 for sandblasting	SAHARA ALUMINIUM OXID 80 μm	1799872	99.7% aluminum oxide	SHERA Werkstoff-Technologies, Germany
110 μm Al_2O_3 for sandblasting	SAHARA ALUMINIUM OXID 110 μm	1789003	99.7% aluminum oxide	SHERA Werkstoff-Technologie, Germany

The wax pattern disc was fabricated with the exact dimensions of ceramic discs (8x3mm), then the wax was scanned, and EXOCAD software was used to design the samples with dimensions of 8 mm in diameter and 3 mm in thickness. Dry milling was done using CAD/CAM milling machine (Ceramill Map400+, Amann Girbach, Germany). For zirconia discs (Z) (n = 30), sintering was done using a high-temperature furnace (Ceramill® Therm, Amann Girbach) according to the manufacturer's instructions. Zirconia discs were placed on the firing tray of the furnace. The sintering cycle was as follows: temperature was raised in two hours to reach 1500°C, holding at 1500°C for another 2 hours, and then the specimens were cooled slowly to less than 100°C in 1 hour. After sintering, the furnace was opened, and the discs were left to cool down to room temperature. For Vita-Enamic (VE) discs (n = 30), wet milling was done from VE blocks by using the Ceramill® Motion 2 CAD/CAM machine. One surface of the discs was wet-ground using 600-grit silicon carbide (SiC) paper. The VE polishing set was used to finish and polish each disc in accordance with the manufacturer's specifications. Pink polishers of VE polishing set were used with water at 7000–10000 rpm. The high-gloss polishing was done with the grey diamond-coated polishers of the VE polishing set at 5000–8000 rpm.

All ceramic discs were carefully checked using magnifying lenses and examined for any surface defects. The thickness and diameter of all discs were checked at different points on each disc and at the borders using a digital caliper. The untreated surfaces were marked by a red water-proof pen to be easily identified from the treated surfaces.

2. Composite disc fabrication:

A split Teflon pattern was used for the fabrication of sixty light-cured composite resin discs (4mm×3mm) (Reflectys light-cured composite resin, ITENA®, Villepinta-France) that were constructed incrementally in accordance with the manufacturer's guidelines. Each incremental layer was polymerized for 20 sec at 600 MW/cm² using a light-curing apparatus (UniXS, Heraeus Kulzer, Wehrheim, Germany) at a distance of 3mm from various directions. To create a smooth surface, a glass slide was placed over the final layer. The discs were polished and examined for excess.

3. Specimen grouping:

In the present study, six groups (n=10) were used according to the type of used ceramics and alumina particle sizes, as follows:

Group 1 Z40: Zirconia discs were air-abraded with Al_2O_3 particles of size 40μm.

Group 2 Z80: Zirconia discs were air-abraded with Al_2O_3 particles of size 80μm.

Group 3 Z110: Zirconia discs were air-abraded with Al_2O_3 particles of size 110μm.

Group **4 V40:** Vita enamic discs were air-abrasive with Al_2O_3 particles of size 40μm.

Group 5 V80: Vita enamic discs were air-abraded with Al_2O_3 particles of size 80μm.

Group 6 V110: Vita enamic discs were air-abraded with Al_2O_3 particles of size 110μm.

The intaglio surface of the ceramic disc to be sandblasted was marked with a black color to function as a guide for complete surface sandblasting upon color removal. Aluminum oxide 40, 80, and 110 μm were applied for 10 sec. from a 5 mm distance vertically at 0.2 MPa using a sandblasting device (Renfert Basic ECO Sandblaster 29492025, Germany). All discs were cleaned with 95% ethyl alcohol for 5 min using an ultrasonic cleaning device (MCS ultrasonic device, China), then rinsed and dried for 1 min. using an oil-water-free air dryer.

4. Surface conditioning and bonding of ceramic discs:

At first, all ceramic discs were adjusted in their place in a cementation device (a homemade device made in Fixed Prosthodontics Department, Faculty of Dentistry at Mansoura University) used during bonding procedures to maintain the bonded specimens in a fixed position and under static load until the setting is accomplished. The ceramic disc surfaces were treated with ceramic primer (Monobond N) that was applied by a microbrush for 1min on the bonding surface, and then fully removed with a strong jet of air or water spray for 30 sec, and it was dried for an additional 30 sec. as directed by the manufacturer.

The composite discs were bonded to the ceramic discs that had been sandblasted previously using resin cement. Cementation was done using adhesive resin cement (Multilink® N, Ivoclar Vivadent AG). Equal amounts of the base and catalyst pastes were applied to the treated ceramic surfaces after being mixed using an auto-mixing tip. The cementation device was loaded after composite discs were inserted. A light curing apparatus (UniXS, Heraeus Kulzer, Wehrheim, Germany) was used, and the cementing assembly was light cured for 40 sec on all sides. Furthermore, all specimens were subjected to a 2 kg static load for 5 min. [26] Bonded specimens were left for two hours before water storage, then stored in a water bath at 37°C for three months.

5. Artificial ageing (Thermocycling)

After three months of water bath storage, the specimens were thermally cycled using a thermocycler device (Thermocycler TC21, Robota, Alexandria, Egypt) between 5 and 55°C for 3000 cycles[27] a 30 sec dwell time and a 10 sec. transfer time. Specimens were dried for the bond strength test after being artificially aged.

6. Shear Bond strength measurement

Shear bond strength (SBS) at ceramic/composite disc interfaces was measured. An Instron (R) product called Bluehill Lite Software was used to test the shear bond strength. A computer-controlled testing apparatus (Model 3345; Instron Industrial Products, Norwood, USA) containing a 5 KN load cell was used to mount each specimen separately and horizontally. The data were recorded using computer software (Instron Instruments Bluehill Lite). A metal bar with a mono-bevelled chisel shape, which was connected to the upper movable part of the testing machine, moved at a crosshead speed of 0.5 mm/min. until debonding occurred. The SBS value was calculated from the maximum debonding force (Newton) for each specimen.

7. Scanning Electron Microscope (SEM)

To evaluate the surface characterization of zirconia and vita enamic hybrid ceramic after debonding for mode of failure examination, SEM was used. Each specimen was air dried, mounted on copper stubs, and then coated with a thin layer of gold (Sputter Coating Evaporator, SPI-Sputter Coater, USA) before being inspected with a scanning electron microscope (SEM) (JEOL.JSM.6510LV, Japan) at different magnifications [24] The failure modes were classified as cohesive failure, which refers to a complete fracture within the ceramic or composite resin; adhesive failure, which means a fracture between the ceramic (or composite resin) and bonding agent; and mixed fracture, which indicates a fracture involving two materials.

8. Statistical analysis

Social Package for Statistical Science (SPSS) software, version 26.0, was used to perform statistical analyses on the data that had been collected. At each study level, two-way ANOVA and serial one-way ANOVAs have been carried out for statistical analysis. Following that, at $P<0.05$, the post-hoc Tukey (HSD) test was performed.

RESULTS

Shear Bond Strength Test (SBS):

The data were tabulated, processed, and analyzed using the statistical package for social science (SPSS) version 26.0 computer programs to find and describe the (Mean and standard deviation) of SBS quantitatively. The mean SBS in N and the standard deviation of the composite bonded to Zirconia and Vita-enamic ceramics treated with different Al_2O_3 particles shown in **Table 2.**

TABLE (2) Mean and Standard deviation of SBS of Zirconia and Vita-enamic ceramics using three Alumina particle sizes followed by primer application.

Groups	N	Mean	Std. Deviation	Minimum	Maximum
Z 40	10	23.8	4.2	18.1	29.5
Z 80	10	64.1	20	35.2	99.1
Z 110	10	68.6	20.7	43.2	113.9
V 40	10	57.9	9.2	42.6	68
V 80	10	99.5	11.5	82.4	122
V110	10	119.6	16.6	96	145.5
Total	60	72.3	34	18.1	145.5

Z= Zirconia, V= Vita-Enamic

A two-factor ANOVA model was used to evaluate the mean shear bond strength (N) of all studied specimens. The interaction of ceramic materials and different particle sizes was not significant ($P = 0.2$). While ceramic materials ($P = 0.000$) and Al_2O_3 particle size ($P = 0.000$) were significant. **(Table 3)**

For pairwise comparison between different test groups, the Post Hoc Tukey (HSD) test was performed at ($P<0.05$). Regarding ceramic material, Vita-enamic showed the highest mean value of SBS (92.4±28.9) compared to zirconia ceramic (52.2±26.1). Considering Al_2O_3 particle size, 110μm showed the highest SBS mean value for VE and Z groups (119.6±16.6), (68.6±20.7) respectively, followed by 80μm for VE and Z groups (99.5±11.5), (64.1±20.1) respectively, and the lowest one was 40μm for both VE and Z groups (57.9±9.2), (23.8±4.2) respectively. There were statistically significant differences between the majority of tested groups (P =0.0001) regarding ceramic materials and Al_2O_3 particle size. The other tested groups showed no statistically significant difference as follows: (Z80, Z110 as P = 0.1), (Z80, V40 as P = 0.9), and (Z110, V40 as P = 0.6). Post-hoc tests confirmed that the 40μm groups had the lowest effect on both types of ceramics among the three surface treatment materials used. **(Table 4)**

The failure mode of each group was examined by SEM at various magnifications in this in vitro study. The debonded specimens mostly exhibited a mixed failure mode, especially in the Z40 and V40 groups, while the other groups (80 μm and 110 μm) the most specimens showed mainly cohesive failure and the most of cement adhered to the ceramic surface. The adhesive failure mode was minimal. **(Fig. 1)**

TABLE (3) Two-Way ANOVA test for ceramic materials and particle sizes and their interaction.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	56179.681[a]	5	11235.94	50.2	.000	0.82
Intercept	313308.232	1	313308.23	1401.1	.000	0.96
Zirconia-Vita enamic (30x30)	24214.196	1	24214.196	108.284	.000	0.67
Al_2O_3 particle size (20x20x20)	31086.443	2	15543.221	69.51	.000	0.7
Ceramic material x Particle size	879.042	2	439.5	1.97	0.2	0.07
Error	12075.391	54	223.62			
Total	381563.304	60				
Corrected Total	68255.072	59				

a: R Squared = 0.823 (Adjusted R Squared = 0.807)   df = degree of freedom   F= ratio of two variances

TABLE (4) Post Hoc Tukey (HSD) test at ($P<0.05$) of all test groups.

Groups	Mean ± SD	Z 40	Z 80	Z 110	V 40	V 80	V 110
Z 40	23.8 ± 4.2		0.000*	0.000*	0.000*	0.000*	0.000*
Z 80	64.1 ±20.1	0.000*		0.1	0.9	0.000*	0.000*
Z 110	68.6± 20.7	0.000*	0.1		0.6	0.000*	0.000*
V 40	57.9 ± 9.2	0.000*	0.9	0.6		0.000*	0.000*
V 80	99.5±11.5	0.000*	0.000*	0.000*	0.000*		0.05*
V 110	119.6±16.6	0.000*	0.000*	0.000*	0.000*	0.05*	

**** Indicates statistically significant differences***

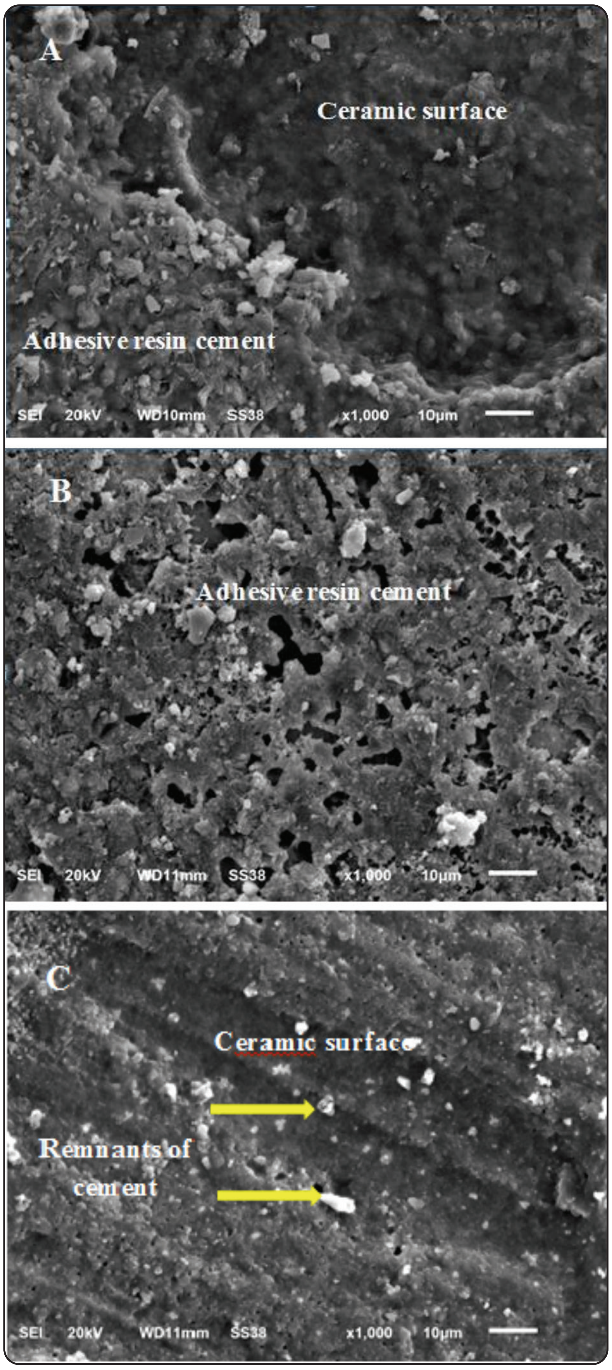

Fig. (1) shows SEM images of different failure modes of treated ceramic surface at magnification 1000X. A-mixed failure mode of 40µm specimens; B-cohesive failure mode of 80µm and 110µm specimens showing resin cement adhered completely to all ceramic surface; C-adhesive failure as most of the ceramic surface is free from cement.

DISCUSSION

This in vitro study aimed to evaluate the effect of different surface treatments on the shear bond strength of CAD/CAM-fabricated ceramic restorations using different alumina particle sizes. There was a change in the SBS based on the type of ceramic material and alumina particle sizes, followed by primer application, so the hypothesis of this study was rejected.

In this research, two types of machinable ceramics were used, such as Zirconia and Vita-Enamic. The most widely used material type for all-ceramic restorations is yttria-partially stabilised tetragonal zirconia (Y-TZP) ceramics due to their superior mechanical properties, especially in regions with strong functional forces.[13] Monolithic zirconia restorations without veneering ceramic were introduced in order to solve the problem of porcelain veneer chipping and to enhance the success rate of zirconia-based restorations. [28]

In order to carry out this research, CAD/CAM technology has been used for manufacturing the zirconia specimens utilizing the monolithic zirconia system (IPS e.max® ZirCAD). Other investigations have shown improved results with monolithic zirconia restorations in laboratory and clinical settings.[13,29,30]

The ceramic discs, especially the zirconia samples in the current study, have been bonded to composite resin discs instead of dental tissues. Because dentin has a heterogeneous microstructure, using dental tissue could lead to discrepancies in analyzing bond strength data. However, the homogenous structure of the composite resin discs would prevent such an incident from arising. [31]

The Vita Enamic material was also selected in this study due to its novel composition of a three-dimensional (3D) ceramic network penetrated with a monomer mixture, which results in a greater Weibull modulus and a less brittleness. [15,32] Because Vita Enamic materials are less rigid than other ceramics, the opposing dental tissues are exposed to reduced wear on the level of clinical use and are easily manufactured by a milling machine. Furthermore, compared to ceramic, composites are less brittle and may be effectively repaired, which reduces chipping and fracture formation during the manufacturing process.[33, 34]

Adhesion to Y-TZP ceramics has gained more attention in recent years. This is due to the ceramics' resistance to hydrofluoric acid conditioning owing to their microstructure and chemical composition. Thus, the varieties of Y-TZP surface preparation techniques that are currently developed are being used to increase resin cement's bonding strength.[35,36]

The problem of zirconia bonding and cementation becomes increasingly important. Adhesives cannot be applied to zirconia using conventional methods since it cannot be etched like glass or other ceramics. It is important to establish zirconia adhesive procedures that are reliable and safe in order to satisfactorily complete the treatment plan.[37] Consequently, a wide range of primers, adhesives, and zirconia surface treatments have been evaluated, as well as resin cement types. However, until present, adhesive cementation requires a well-defined process that yields dependable and clear effects.[22, 38]

In the current study, Monobond N was applied to the ceramic surface after air abrasion. As a result, this universal primer has the same adhesive component 3-methacryloxyprophyl-trimethoxysilane (MPS) that forms a chemical bonding to zirconia ceramics that have a silica coating on them. Additional ingredients, like sulphide and phosphoric acid methacrylates, could be added to improve the chemical adhesion to oxide ceramics and other prosthetic materials.[39, 40]

Because oxide ceramics have low silica content, such as zirconia and alumina, they require enhanced techniques to provide higher bond strength.[41, 42] Additionally, surface preparations appear to be required for bonding the composite resin to these ceramics since the irregularities created during the manufacturing and milling processes of ceramic do not give an appropriately high bond strength. Increasing micromechanical retention can be achieved by a variety of techniques, including air abrasion with aluminum oxide particles and mechanical surface roughening using a diamond bur.[43] There is still debate regarding the ideal size of Al_2O_3 particle to be used during sandblasting the surface of zirconia ceramics to increase the bonding strength with resin cement.[44]

In this study, ceramic specimens underwent 3000 thermocycles between 5 °C and 55 °C with a 30 sec dwell time and a 10 sec transfer time in order to replicate the temperature variations that occur in the oral cavity when eating, drinking, or breathing, which could cause stress on adhesive interfaces. This enabled the luting cements to become saturated with water, simulating the oral environmental conditions.[27, 45]

In clinical situations, shear pressures are the main cause of adhesion and can lead to a failure in the restorative materials' bonding.[46] This study evaluates the bonding strength of resin cement and ceramics using the most popular bond strength test, the shear bond strength test (SBS). It has the advantages of being fast and easy to perform.[47]

The present study's results indicate that, with regard to the type of ceramic material used, Vita-enamic exhibited the highest mean value of SBS when compared with zirconia ceramic. When Al_2O_3 particle size was taken into account, both VE and Z groups had the greatest SBS mean value at 110μm, followed by groups with 80μm, and the lowest one was 40μm groups.

The results of Vita-enamic are provided in relation to the mechanical and chemical pre-treatments of the bonded surfaces, which are necessary to achieve sufficient bond strength for Vita-enamic materials.[48,49] The chemical bonds formed between resin cement and resin-based restorative materials, as well as the use of primers containing phosphoric acid monomers on wet polymeric resin surfaces, both significantly enhance adhesive bonding.[48, 50] Additionally, surface bonding may be improved by micromechanically pretreating hybrid ceramics with aluminium oxide (Al_2O_3) particles to increase surface area and chemically activate the bonding surface by removing organic contaminants. By producing a micro-retentive surface, the Al_2O_3 sandblasting process modified the resin cement's surface, allowing for mechanical interlocking.[51] Another explanation could be that, in contrast to zirconia, vita enamic has a porous network of feldspathic ceramic reinforced with alumina and only one urethane dimethacrylate polymer infiltrate, which improves the effectiveness of the airborne-particle abrasion technique.

As compared to specimens abraded with 40 and 80 µm Al_2O_3, the results of this study confirmed that specimens air-abraded with 110 µm alumina produced greater SBS values. The explanation for this is that the use of coarser alumina particles in air abrasion led to an increase in surface irregularities. These irregularities then increased the surface area available for bonding with the luting material, improving the micro-mechanical retention and ultimately increasing the bond strength values.[52] This is consistent with the findings of the SEM analysis and bond strength tests, which showed that the ceramic material's strength increased when the size of the particles used for air abrasion was increased from 40 µm to 110 µm.

The results of current study showed that, sandblasting was an essential step in creating a long-lasting bond between the luting agent and the ceramic when combined with MDP monomers found in either the cement itself or the adhesive primer (as in the current study), these findings are in agreement with study of Abed et al., (2023). [25]

Following the sandblasting of ceramic surfaces, Monobond universal primer was applied. There is some evidence to suggest that Y-TZP ceramics' adhesive bonding could be improved by the use of compounds with a chemical affinity for metal oxides. In order to create a water-resistant bond with densely sintered zirconia ceramic, phosphate ester monomers, such as MDP (10-methacryloyloxyi-decyl-dihydrogenphosphate), chemically react with zirconium dioxide.[25] Because of this, the treated test groups of both ceramics exhibited double chemical bonding, and the enhanced bond strength was also a result of micromechanical retention.

Although Vita enamic ceramic reported higher SBS than zirconia, one explanation that might be offered is that the bond strength to zirconia varied because of the varying resistance to hydrolysis of the various functional phosphoric acid and methacrylate groups in Monobond N (MN). According to Hajja et al. (2023), [53] another explanation might be the inclusion of silane in the mixture (as in the case of MN), which enhances the wettability of zirconia and bonds to the resin cement.

In the current study, adhesive resin cement (Multilink®N) was used to bond the ceramics and composite resin discs. Rather than using acidic phosphate monomers, Multilink®N's formula contains silica fillers, dimethacrylate, and HEMA, which are responsible for its superior mechanical properties.[20] According to the manufacturer, the flexural strength under dual curing conditions can approach 110 MPa. In addition to its excellent mechanical abilities, Multilink®N resin cement is recommended due to its durable bond strength, as demonstrated by previous studies.[54, 55]

Scanning electron microscopic examination revealed that the majority of the deboned specimens, particularly those in the Z40 and V40 groups, displayed a mixed failure mode. In contrast, the majority of the specimens in the other groups (80 μm and 110 μm) primarily displayed cohesive failure, with the cement adhering entirely to the ceramic surface. There was a minimal adhesive failure mode. Cohesive and mixed failure patterns appear more acceptable as they show better infiltration of the resinous cementing agent into the conditioned surface of the ceramics. On the other hand adhesive failure patterns have been associated to low bond strength values.[56]

One limitation of the present study is that a single type of adhesive resin cement and ceramic primer were examined. Moreover, more research is required to examine bond degradation in the difficult intraoral circumstances.

CONCLUSIONS

Within the limitations of this study and based on the results, the following conclusions were drawn

1. Surface roughness of tested groups increased significantly as the size of the aluminium oxide particles increased.
2. Regardless of the type of ceramic used, higher SBS could be achieved by increasing the degree of surface roughness.
3. The ceramic primer application after 110 μm sandblasting has been proposed to be the best result of the current research.

Conflict of Interest

There were no declared conflicts of interest by the authors.

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