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Effect of novel pre-sintered zirconia surface treatment on shear bond strength between zirconia and veneering porcelain compared to conventional surface treatments: an in-vitro study

Efeito de um novo tratamento de superfície de zircônia pré-sinterizada na resistência ao cisalhamento entre zircônia e porcelana em comparação com os tratamentos de superfície convencionais: estudo in vitro

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ABSTRACT

Objective: to evaluate the effect of novel zirconia surface treatment method on shear bond strength between zirconia and veneering porcelain compared to air abrasion and CoJet surface treatment methods. **Material and Methods:** twenty-one zirconia ceramic discs were fabricated with diameter of 7mm and 3mm thickness and divided according to surface treatment into three subgroups, control group I: Air Abrasion (n=7), group II: CoJet (n=7) and group III: Z-etch (n=7). Porcelain was built over the zirconia specimens with a customized mold and fired in a ceramic furnace. All specimens were thermocycled (20000 cycles) between 5°C – 55 °C with a dwell time of 30 seconds in distilled water and shear bond strength of veneering porcelain to each zirconia specimen was tested using a universal testing machine. **Results:** numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). One-way ANOVA test was used to compare between the groups. There was a statistically significant difference between the three groups (P-value = 0.002, Effect size = 0.503). Pair-wise comparisons between groups revealed that Z-etch showed the statistically significantly highest mean shear bond strength. **Conclusion:** zirconia coating using z-etch is showing promising results in promoting higher bond strength than conventional surface treatment methods as air abrasion and silica coating.

KEYWORDS

Air-abrasion; Dental materials; Shear bond strength; Surface treatment; Z-etch; Zirconia.

RESUMO

Objetivo: avaliar o efeito do novo método de tratamento de superfície de zircônia na resistência ao cisalhamento entre a zircônia e a porcelana de cobertura em comparação com os métodos de abrasão a ar e jateamento com CoJet. **Material e Métodos:** vinte e um discos de zircônia foram confeccionados com diâmetro de 7mm e espessura de 3mm e divididos de acordo com o tratamento de superfície em três subgrupos, grupo controle I: Abrasão a ar (n=7), grupo II: CoJet (n=7) e grupo III: Z-etch (n=7). A porcelana foi aplicada sobre os espécimes de zircônia com um molde personalizado e sinterizada em forno de cerâmica. Todos os espécimes foram termociclados (20.000 ciclos) entre 5°C - 55°C com um tempo de permanência de 30 segundos em água destilada e a resistência ao cisalhamento da porcelana de cobertura foi testada através de uma máquina de ensaio universal. **Resultados:** os dados numéricos foram avaliados quanto à normalidade, verificando a distribuição dos dados e utilizando testes de normalidade (testes de Kolmogorov-Smirnov e Shapiro-Wilk). O teste ANOVA de um fator foi utilizado para comparar os grupos. Houve uma diferença estatisticamente significativa entre os três grupos (P-valor = 0,002, tamanho do efeito = 0,503). As comparações pareadas entre os grupos revelaram que o Z-etch apresentou a resistência de união ao cisalhamento estatisticamente significativamente mais alta. **Conclusão:** o revestimento de zircônia utilizando Z-etch mostrou resultados promissores para o aumento da resistência de união em comparação aos métodos convencionais de tratamento de superfície, como abrasão a ar e revestimento de sílica.

PALAVRAS-CHAVE

Abrasão dental por ar; Materiais dentários; Resistência ao cisalhamento; Tratamento de superfície; Z-etch; Zircônia.

INTRODUCTION

Restoring optimum esthetics and function in restorative dentistry has always been limited by lack of advanced materials that can provide both esthetics and withstand occlusal forces. This idea has greatly changed in the past few decades due to advancements in material science and introduction of recent generations of dental zirconia [1]. Zirconia has been through a long journey of material science research and subsequent advancements to tweak its properties to meet the goal of esthetics and function. Among these methods was the addition of stabilizing oxides as yttria to help make the material in its strongest form possible at room and mouth temperature [2]. This resulted in a phenomenon of transformation toughening, which can only resist primary cracks but cannot resist any secondary forces in the same area where the crack was arrested before [3-5].

On the other hand, bonding to zirconia was a challenge as well due to lack of silica content within the material that can provide chemical bonding to either silica in the veneering porcelain or to resin cement. To overcome such problem, many materials and methods have been introduced to modify the surface of zirconia by increasing surface area available for bonding [6].

The use of air abrasion in treating the surface of zirconia has been advocated in literature and widely used to enhance the bonding to zirconia. The use of several particles has been studied and 50 μm aluminum oxide particles are the most used particles in blasting zirconia surface to create micro irregularities or roughness to enhance micro mechanical interlocking with either resin cement or veneering porcelain [5,7].

CoJet method has also been introduced to modify the surface of zirconia by addition of silica particles to the aluminum oxide particles to embed them in the surface of zirconia and provide a chemical bond between embedded silica and resin cement [8-11]. However, due to the nature of the application of both methods, the blasting action of aluminum oxide particles adversely affects the mechanical properties of zirconia. The energy caused by the collision between aluminum oxide and zirconia results in phase transformation from the higher strength tetragonal phase into less resistant to crack and weaker phase called monoclinic phase. Many studies have confirmed the high concentration of monoclinic phase on the surface of zirconia after air abrasion and subsequent phase transformation [12-14]. That created a need for a new surface treatment method that can be applied safely without any adverse effects to the zirconia or the operator and can prevent the creation of monoclinic phase after its application to avoid weakening the material and shortening its service time in the oral environment. In addition, can create good bond strength between zirconia and veneering porcelain or resin cement [2].

A novel approach composed of a suspension (Z-etch, IDS CAD, USA) was introduced to enhance the surface of zirconia for better bonding. This suspension is constituted of zirconia nano particles and carbon particles suspended in distilled water with specific concentration. The method of application is by brushing it over the surface of zirconia before sintering to create surface roughness. While some authors compared the effect of z-etch using different concentrations, others compared it to other less common methods as hydrofluoric acid or nontreated zirconia as control group. No scientific research has compared this material to other well-established methods such as CoJet and air abrasion to find out its performance in comparison to them [15-18].

The aim of this study was to evaluate the effect of novel zirconia surface treatment method on shear bond strength between zirconia and veneering porcelain compared to air abrasion and CoJet surface treatment methods. Fractured specimens were analyzed using stereomicroscope to determine the mode of bond failure. The null hypothesis tested was that z-etch surface treatment does not have a significant difference from other surface treatment methods regarding shear bond strength values between zirconia and veneering porcelain.

MATERIAL AND METHODS

Yttria stabilized zirconium oxide discs (3Y-TZP) used for core manufacturing of the discs used as core materials (Bio ZX2, Dental Direkt GMBH, Germany). Feldspathic porcelain used as a veneering material over the zirconia discs to test the shear bond strength between the two materials after different surface treatment (Ceramco PFZ, Dentsply Sirona, USA) (Table I).

Air abrasion

Fifty μm aluminum oxide particles were used to performing the air-abrasion method.

CoJet

CoJet (3M, ESPE) was used to perform silica coating. CoJet is composed of silica and aluminum oxide powders. The aim of CoJet sand blasting was to embed silica particles into the surface of zirconia and thus modify the surface to be more chemically bondable.

Z-etch

Z-etch (Z-etch, IDS CAD, USA) was the novel material used to modify the zirconia surface before sintering procedure. It is composed of zirconia and carbon nanoparticles suspension. The aim of the application of the material was to increase the zirconia surface area, roughness, and porosity.

Sample size

Sample size was determined based upon the results of a pilot study conducted on three specimens in each group, the effect size (f) for one-way ANOVA was 0.895. Using alpha (α) level of (5%), β level of 0.8 (Power = 80%); the minimum estimated sample size was a total of 18 specimens (6 specimens per group). Sample size calculation was performed using G*Power version 3.1.9.2

Twenty-one zirconia discs were designed in CAD software with dimensions of 7mm diameter and 3mm thickness and then subdivided into 3 subgroups according to surface treatment, control group I: Air Abrasion (n=7), group II: CoJet (n=7) and group III: Z-etch (n=7).

Twenty-one porcelain discs were molded and fired over the zirconia discs to reach final dimensions of 5mm diameter and 3mm thickness.

Table I - Showing materials used in this study

Material	Manufacturer	Chemical Composition	%
Bio ZX² Zirconium	Dental Direkt GmbH, Germany	Zirconium oxide	70-100%
		Aluminum oxide	0-1%
		Yttrium oxide	3-15%
		Hafnium oxide	1-5%
Ceramco PFZ	Dentsply Sirona, USA	Sodium Potassium Aluminosilicate SiO2, Al2O3, Na2O, K2O, SnO2, CeO2, Pigments, 1.3-Butanediol Xi	Not mentioned
Z-etch	Dmax	Zirconium Dioxide	≤15%
		Water	≥85%
		Carbon	not mentioned
CoJet	3M ESPE	Aluminum Oxide	> 95%
		Synthetic Amorphous Silica, Fumed,	< 5%
		Crystalline free	

Sample preparation

Dental direct zirconia-based disc (DDBioZX2) was selected with a diameter of 98.5mm and thickness of 16mm and scaling factor of 1.237 which was predetermined by the manufacturer to compensate for the shrinkage of the zirconia after the sintering process.

Zirconia discs were designed using CAD software (Fusion 360 2.0.15293 x86_64) with the desired dimensions (7mm diameter and 3mm thickness). After completion of the design, the digital .stl files were loaded in the CAM software of the milling machine (Dental CAM 7, Vhf GMBH, Germany). The milling process and machine milling strategy were fully automated processes without any interference in a dry mode as required by the manufacturer and the machine milling strategy with the required zirconia milling burs (Vhf S1, VHF GMBH, Germany).

After completion of the milling procedure, zirconia discs were separated from the discs using a diamond coated bur. In addition, 600,800,1000,1200,2000 grit sandpaper were used to standardize the surface of the samples. Each sample was moved in 4 directions (right, left, up, down) by the same operator 10 times in each direction per sandpaper so that all specimens were subjected to the same pressure at the same time from the operator.

After sanding the discs, they were submerged in a closed bottle containing distilled water and placed in an ultrasonic cleaner to clean the surface of the samples from all residues from the sanding and surface finishing process. The samples were left for 10 minutes in the ultrasonic cleaner. After ultrasonic cleaning, steam cleaner was used to clean the surface then air dried in an electric oven for 20 minutes at 200 °C.

After cleaning, an online research randomization software (randomizer.org) was used to allocate each sample to its designated testing group randomly.

Z-etch application

According to recommendations of the manufacturer and due to the nature of application, z-etch was applied before sintering process to its subgroup. The z-etch bottle was shaken well and dispensed in a small porcelain palette. A brush was used to paint it over the surface of the specimen in one coat according to manufacturer's instructions. It is important to note that number of layers or coats of application can affect the resultant shear bond strength [16].

Sintering process

The discs were placed over zirconia beads in a plate inside the sintering furnace (Roko Tytan Zr II, Poland) and sintering parameters were inserted according to the manufacturer's sintering schedule. The time for the sintering cycle was 9.2h (Table II).

Surface treatment and porcelain buildup

Before application of Air abrasion and CoJet surface treatments 2 devices were designed in CAD software (Fusion 360 2.0.15293 x86_64) and 3d printed to ensure the standardization of tip of the surface treatment device in terms of distance and angle between the tip and the specimen. Device A was used with Air abrasion method and device B was used with CoJet method to accommodate the different designs of handpiece used for each method.

Air abrasion

Device A was used to align the tip of the sandblasting device in a perpendicular direction

Table II - Showing sintering schedule of the zirconia discs as recommended by the manufacturer

	Temp. 1 [°C]	Temp. 2 [°C]	Heating rate [°C/h]	Heating rate [°C/min]	Dwell time [min]	Time [min]
Heating	20	900	480	8		110
Dwell	900	900			30	30
Heating	900	1450	3	3		165
Dwell	1450	1450			120	120
Cooling	1450	200	600	10		125
					Total Time:	550 9.2h

to the surface of the sample and at 10mm distance from the surface. The device was used inside the air abrasion chamber and at an air pressure of 2.8bar and the particles used for air abrasion were 50μm aluminum oxide particles for 10 second duration per sample (Figure 1a).

CoJet

Device B was used with CoJet powder to align the tip of the contra angle handpiece at perpendicular direction to the sample and at 10 mm distance. CoJet sand was added and air flow of 2.8bar were allowed for 15 seconds per sample to allow the CoJet particles to blast the surface of the discs (Figure 1b).

After surface treatment, discs were ultrasonically cleaned in distilled water to clean the surface from residues. Steam cleaner was additionally used to clean the surface of the specimens followed by air drying using oil free air.

Porcelain mold

A mold was used as a housing to accommodate the porcelain dough and adapt it to the surface of the overlying zirconia disc with the required dimensions of 5mm diameter and 3mm thickness. The mold was designed using 3d CAD software (Fusion 360 2.0.15293 x86_64) and 3d Printed using a desktop LCD 3d Printer (Phrozen Mighty 4K, Phrozen Inc., Taiwan) with the recommended 3d printing parameters for the selected resin (Phrozen Aqua Grey 4K).

Porcelain discs were made by direct application over the treated zirconia discs. A specially designed porcelain mold was made in fusion 360 CAD design software with internal dimensions to make a 5mm diameter x 3mm thickness porcelain discs. However, due to the shrinkage of the porcelain discs after firing, the dimensions of the resulting disc was used to modify the mold dimensions to be able to deliver the exact dimensions of the porcelain discs after firing to be 5mm x 3mm (Figure 2).

By measuring the feldspathic disc dimensions after firing and comparing it to the planned dimensions, a simple mathematical equation was used to determine the needed dimensions of the mold to compensate for the shrinkage of the porcelain after firing and get the exact final dimensions needed after firing for the discs which were 5mm diameter x 3mm thickness.

Equation used was as followed:

1- Measured dimension of the porcelain disc after firing = A
2- Measured dimension of the porcelain disc before firing = X which is needed to be planned in the 3d design
3- Measured dimension of the porcelain disc before firing in the pilot study= B
4- Measured dimension of the porcelain disc after firing in the pilot study = C

$$ {}^{A}_{X}X^{B}_{C} \quad \text{Then} \quad \frac{X = A \times C}{B} \qquad (1) $$

After application of the porcelain over the zirconia discs inside the mold the firing program was adjusted in the firing furnace according to manufacturer's firing schedule.

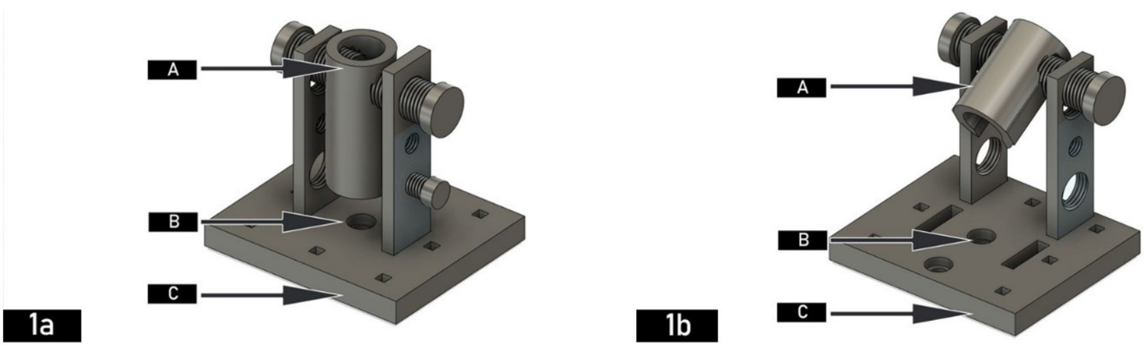

Figure 1 - 3D printed devices to standardize distance and angle for air abrasion and CoJet application (1a) Showing device A used for air abrasion procedure. (A) Cylinder to hold the air abrasion pen perpendicular to the zirconia specimen. (B) Zirconia disc cavity to hold the zirconia disc. (C) Base of the device (1b) Showing device B used to standardize the CoJet application. (A) Cylinder to hold the CoJet handpiece. (B) Cavity to hold the zirconia disc. (C) Base of the device.

AGING AND SHEAR BOND STRENGTH

To simulate clinical aging conditions, all specimens were thermocycled between 5°C – 55 °C for 20000 cycles with a dwell time of 30 seconds in distilled water bath and a transfer time of 10 seconds after surface treatment in a thermo-cycling unit (Julabo FT200, Julabo, Seelbach, Germany).

Shear bond strength was performed using universal testing machine (Instron universal testing machine model 3345, England). Specimens were mounted in lower compartment and mono beveled chisel with a thickness of 0.5mm was used to perform the shear test in a direction parallel to the surface of the disc and at a crosshead speed of 1mm/min.

Measurement of shear bond strength values were calculated by converting the loads into MPa by dividing the maximum failure load (N) by the bonding area (mm^2) saved in excel sheet (Figure 3).

Mode of failure

Mode of failure was analyzed using stereomicroscope (50X magnification) (MA 100 Nikon, Japan) after performing shear bond strength.

Surface roughness analysis

After surface treatment, zirconia surface was inspected at 4,000X magnification using scanning electron microscopy (SEM). Surface roughness

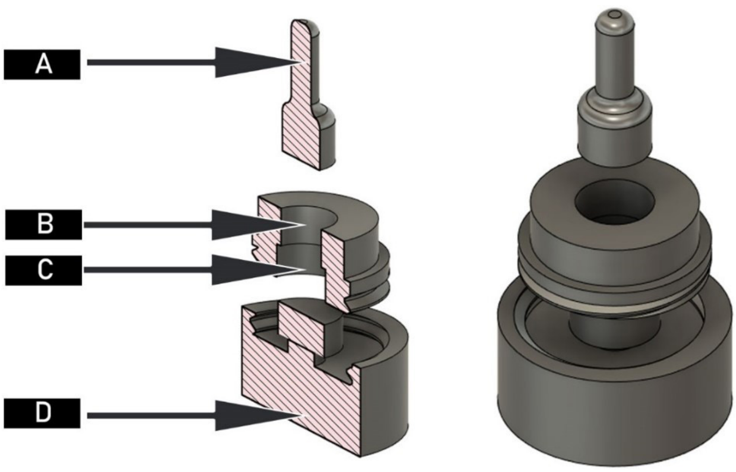

Figure 2 - Showing the 3D printed device for porcelain application over zirconia discs. (A) Piston used for condensing the porcelain. (B) Porcelain molding cavity to hold the porcelain slurry. (C) Zirconia disc cavity that contains the zirconia discs. (D) Base for the device to hold the porcelain mold tightly over the zirconia.

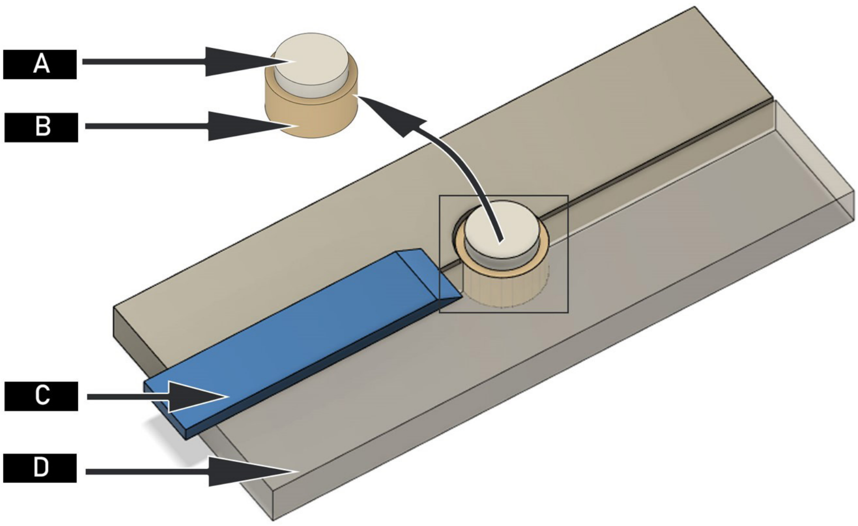

Figure 3 - Graphical representation of shear bond strength test. (A) Porcelain disc. (B) Zirconia Disc. (C) Chisel used to break the sample. (D) Base of the device made from2 components that close on each other to fix the sample between them.

was measured at an area of 100μm width by 60μm height to inspect the surface and evaluate the microscopic effect of the surface treatment on the surface of the sample.

Statistical analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Shear bond strength data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values. One-way ANOVA test was used to compare between the three groups. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Primary outcome shear bond strength

There was a statistically significant difference between the three groups (*P*-value = 0.002, Effect size = 0.503). Pair-wise comparisons between groups revealed that Z-etch showed the statistically significantly highest mean shear bond strength.

CoJet showed statistically significantly lower mean value. Air abrasion showed the statistically significantly lowest mean shear bond strength (Table III) (Figure 4).

Secondary outcome mode of failure

After analysis of the mode of failure. It was divided into 3 categories:

a- Adhesive failure: failure occurs at the interface between the two materials with no remnants of porcelain over the zirconia surface.

b- Cohesive failure: failure occurs predominantly within the structure of the same material whether porcelain or zirconia.

c- Mixed: adhesive failure between 2 materials at the interface with porcelain remnants over zirconia

After inspection of the specimens using the same observer with the above criteria for categorizing the observed failure, it could be found that z-etch showed the highest percentage of mixed failure while air abrasion showed the highest percentage of adhesive failure (Figures 5-6).

Scanning electron microscopy

Scanning electron microscope was used to evaluate the surface of zirconia and the modification occurred at two different magnification levels 4000x and 15000x.Air abrasion and CoJet electron microscope share a common crater like depressions which confirms

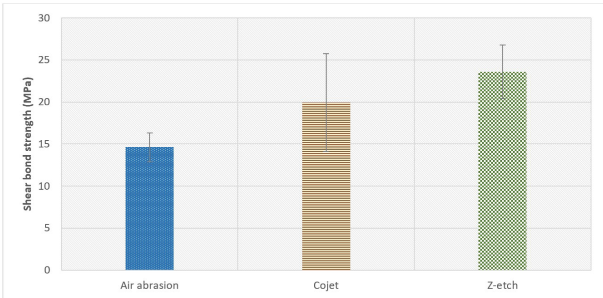

Figure 4 - Bar chart representing mean and standard deviation values for shear bond strength of the three groups.

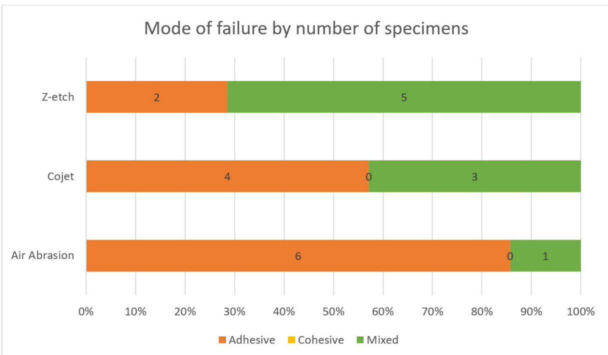

Figure 5 - Mode of failure according to each group.

Table III - Descriptive statistics and results of one-way ANOVA test for comparison between shear bond strength (MPa) of the three groups

Air abrasion		CoJet		Z-etch		*P*-value	*Effect size (Eta squared)*
Mean	SD	Mean	SD	Mean	SD		
14.63 [C]	1.7	19.91 [B]	5.82	23.61 [A]	3.19	0.002*	0.503

*Significant at $P \leq 0.05$.
Different superscripts indicate statistically significant difference between groups.

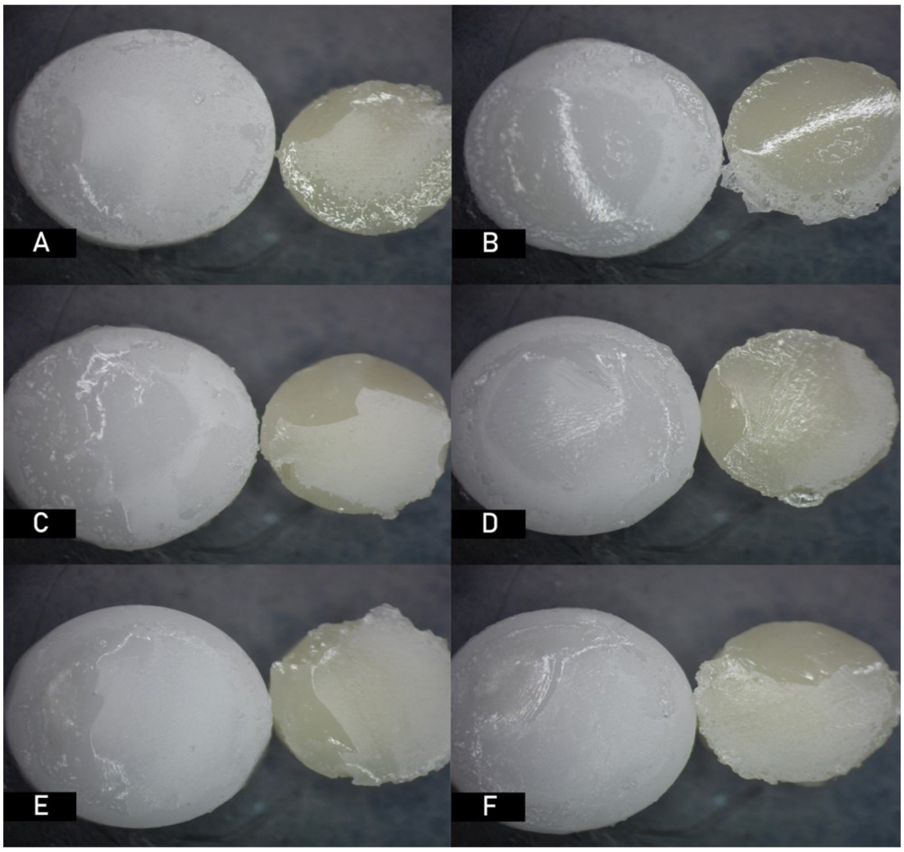

Figure 6 - Mode of failure under stereomicroscope (A) adhesive failure in air abrasion group (B) mixed failure in air abrasion group (C) mixed failure in CoJet group (D) adhesive failure in CoJet group (E) adhesive failure in z-etch group (F) mixed failure in z etch group.

the damage that occurs to the surface of zirconia due to blasting power of the aluminum oxide and silica particles which are needed to increase surface area and roughness of the surface and increase bond strength mechanically (Figure 7).

On the other hand, Z-etch showed a pattern of bead like appearance over the surface of zirconia and with 15000x magnification a cloud or scaffold appearance of zirconia appears with no other sign of damage of the surface of the specimens as it air abrasion and CoJet subgroups (Figure 7).

Surface roughness analysis

Surface roughness analysis showed that the highest mean surface roughness Ra was in case of Z-etch surface treatment (Ra [μm] = 15.97) followed by CoJet (Ra [μm]=15.12) and air abrasion (Ra [μm]= 14.7) (Table IV) (Figure 8).

DISCUSSION

The bonding to zirconia has always been a point of interest in the literature due to its wide applications in the dental field whether for fixed restorations or for implant supported prosthesis. Many methods have been introduced to enhance the bond to zirconia whether from the intaglio side or the external porcelain veneering side.

In the present study, yttria stabilized zirconia (3Y-TZP) was selected as it is the most common used type for veneering technique by porcelain to enhance its esthetic properties and outcome. The compatible porcelain veneering system was selected based on manufacturer instructions for the suitable veneering porcelain systems. Air abrasion as a surface treatment method is the most popular method used for treating the surface of zirconia. In addition, it has been widely used in literature while CoJet silica coating can provide effective bond strength values because of surface modification and silica embedding in the surface of zirconia [6,7,19,20].

The null hypothesis was rejected due to the results that showed significant difference between different surface treatment methods.

The Macro shear bond strength test is the most widely used test in evaluating bond strength

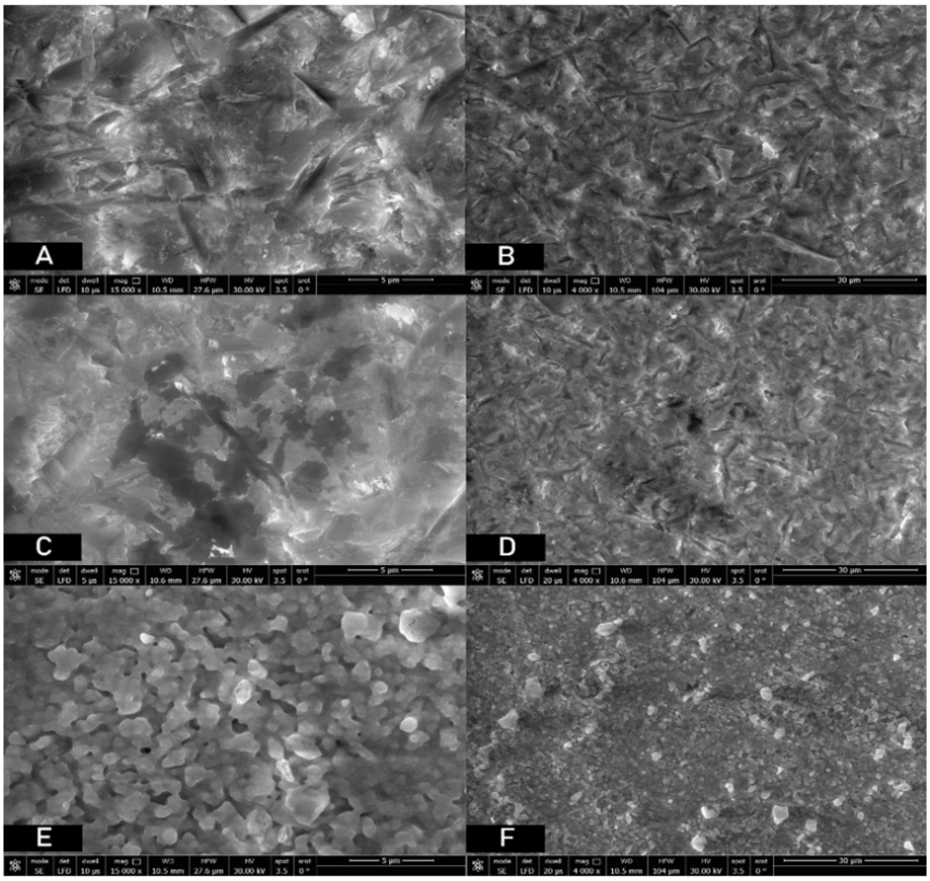

Figure 7 - (A) SEM image of zirconia surface after air abrasion at 15000X magnification (B) SEM image of zirconia surface after air abrasion at 4000X magnification (C) SEM image of zirconia surface CoJet at 15000X magnification (D) SEM image of zirconia surface CoJet at 4000X magnification (E) SEM image of zirconia surface after Z-etch at 15000X magnification (F) SEM image of zirconia surface after Z-etch at 4000X magnification.

Table IV - Showing mean roughness values (Ra) for each surface treatment method

Surface Treatment	Air Abrasion	CoJet	Z-etch
Roughness at 4000x (Ra)	14.7	15.12	15.97

between ceramics and other substructures. The lower incidence of pretest failure is one of the most important features of the shear bond test among other tests. The micro shear bond strength was introduced to analyze the bonding stresses over a smaller area with a more homogenous stress pattern compared to macro shear. However, the use of micro shear and its application was a very technique sensitive procedure that can lead to inconsistent results if not performed accurately. The selection of macro shear bond test was due to its simplicity and the evaluation of secondary outcomes as failures modes can be interpreted easily using this test [21-24].

The dimensions of the samples were estimated to be 7mm diameter and 3mm thickness for zirconia and 5mm diameter and 3mm thickness for porcelain and these dimensions were based upon the ISO standards (ISO 29022:2013) for notched edge shear bond strength test.

When surface treatment is performed on ceramics, variables including air pressure, size of the blasting particles, type of the particles and the distance between the nozzle tip and the ceramic surface are vital factors to consider [1,25-27]. All the specified variables for air abrasion, CoJet and z-etch were based upon manufacturer.

In addition, throughout literature it was found that optimal pressure for air abrasion and CoJet to be around 2-2.8bar and the particle size of air abrasion to be 50μ .These parameters are an important aspect for surface treatment of zirconia as any increase in air pressure or particle size can lead to higher percentage of tetragonal to

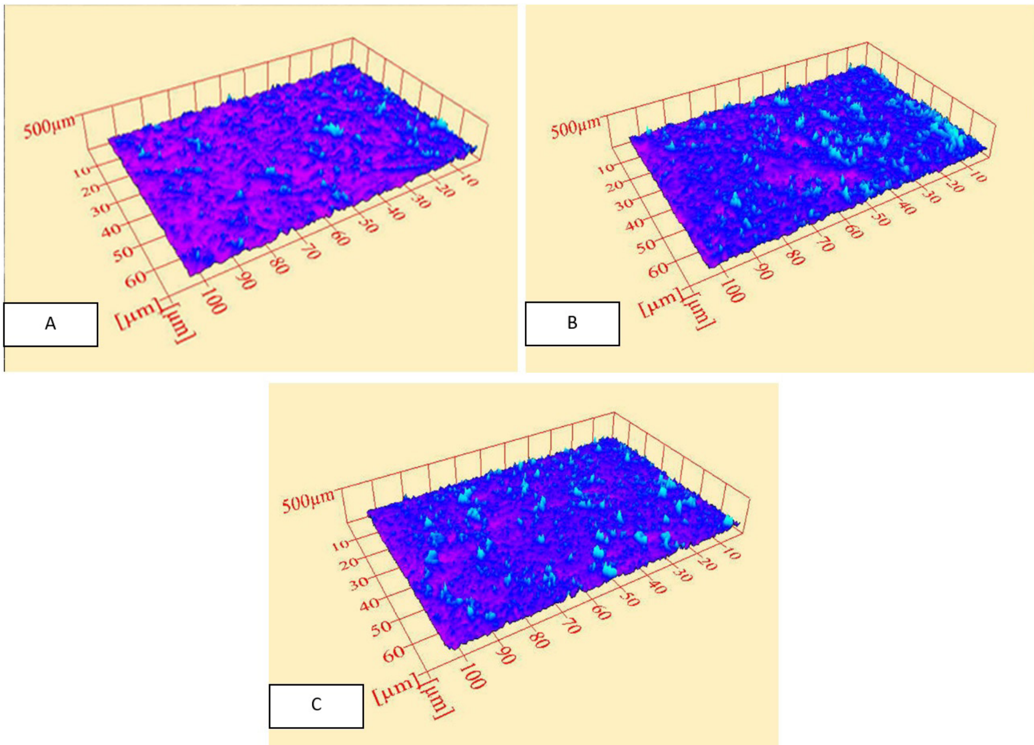

Figure 8 - (A) 3D representation of roughness of the surface (B) 3D representation of roughness of the surface (C) 3D representation of roughness of the surface.

monoclinic phase transformation which weakens the zirconia material and makes it less resistant to stresses under function [5,6, 28-31].

Cleaning the surface of zirconia using distilled water is an important step to make sure of absence of surface contamination. In 2020, Attia and Ebeid [32] evaluated several decontamination methods for zirconia and it was concluded that decontamination method has an impact on shear bond strength to zirconia [32].

Many experimental coatings other than z-etch have been tested in the literature to enhance zirconia bond strength as the use of silica coating technique and the use of Sol-jel dip technique for silica coating [33-35]. On the other hand, graphite using graphite leads was used as well over the zirconia surface followed by Er: YAG laser application as an experimental coating to enhance bond strength which showed higher shear bond strength in comparison to air abrasion [36].

Z-etch was used in this study to prove its effectiveness in comparison to previous methods and to address the drawbacks of conventional methods as phase transformation from stabilized tetragonal phase to monoclinic less resistant to fracture phase due to blasting action to the surface of zirconia and content of aluminum oxide. The basic principle of using z-etch was to implement carbon particles as a carrier for zirconia nanoparticles to provide hydrogen bond between zirconia surface and nano zirconia coating. After sintering procedure, carbon particles evaporate due to high sintering temperature leaving a rough network of zirconia nano particles over the zirconia surface [37].

The application of z-etch suspension could be considered fast, effective, and economic method to modify the surface of zirconia without exposing the zirconia surface to unnecessary stresses and energy that cause phase transformation and subsequent weakening of the material. Acquiring a strong interface between zirconia and veneering ceramic is a critical issue that has been addressed by many researchers. As failure of zirconia is mainly due to lack of proper bond between veneering ceramic and zirconia. In addition, the presence of zirconia surface contaminants and decontamination techniques before porcelain application is a crucial aspect that should be taken into consideration as well. Further research is needed to address this issue as well [32,38].

Z-etch showed the highest mean shear bond strength compared to air abrasion and CoJet and this can be attributed to the mechanism of action of the material as it forms a cloud like layer of zirconia over the surface that can provide a substrate for undercuts and irregularities to engage the porcelain. This could be better than depending solely on roughness made by blasting of aluminum oxide in case of air abrasion and CoJet.

Bae et al. [18] compared the effect of zirconia slurry application over zirconia and used air abrasion with 50 μ and 125 μ particle size as comparator groups. Although Z-etch improved the shear bond strength in that study by it was not higher that air abrasion groups and this can be attributed to different surface conditioning method after surface treatment and substrate as this study used Panavia, superbond and Variolink to test their bond strength to zirconia not as the present study which addresses the outer surface of zirconia that received porcelain layering [18].

Jo et al. [16], studied the effect of zirconia slurry coating as well in 2020 with different concentrations and it was found that zirconia coating enhanced the shear bond strength significantly with the highest value in 50% concentration of zirconia slurry, The substrate bonded to that study was resin cement as well as no previous study studied the effect of z-etch or coating zirconia on the bond strength between zirconia and veneering porcelain [16].

This can be confirmed by inspection of the scanning electron microscope images showing a cloud like appearance of z-etch and by the highest roughness values calculated for z-etch in comparison to air abrasion and CoJet. The increase in roughness values were in accordance with Jo et al. [16], as zirconia coating increases the roughness parameters of the surface by deposition of nano zirconia particles result in a cloud like appearance [16].

On the other hand, CoJet showed significantly higher shear bond strength compared to air abrasion which is in accordance with Baiomy et al. [39] and can be attributed to the embedded silica on zirconia surface and their ability to bond chemically with silica content from porcelain. The measured mean surface roughness of the specimens confirmed this finding as z-etch showed the highest values in mean surface roughness compared to other methods [16]. However, in study by Bae et al. [18] different concentrations of zirconia slurry were evaluated to test their effect on shear bond strength and surface roughness was not measured.

Even though surface roughness increased with increasing the concentration of zirconia slurry, it was found that it does not increase the shear bond strength until a certain concentration is reached. This could mean that there is a bottleneck for concentration of the zirconia slurry and after it shear bond strength can decrease significantly as confirmed by Jo et al. [16]. In addition, mode of failure showed that mixed failure is more prone to occur in z-etch subgroup which can be related to increased shear bond strength and mean surface roughness value in z-etch group.

CONCLUSION

Within the limitations of this study, the application of z-etch to pre sintered zirconia surface could be an effective method to obtain increased bond strength between zirconia and veneering porcelain in comparison to conventional zirconia surface treatment methods.

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Author’s Contributions

AAB: Conceptualization. AAB: Methodology. AAB: Writing – Original Draft Preparation. NNAEH, HAN, AZ: Writing – Review & Editing. HAN, AZ: Visualization. HAN, AZ: Supervision. AZ: Project Administration.

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