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THE INFLUENCE OF AIR ABRASION AND ER,CR:YSGG LASER ON SHEAR BOND STRENGTH OF CUBIC ZIRCONIA TO TWO RESIN CEMENT TYPES

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ABSTRACT

Aim: To examine how various pre-sintering surface treatments affect the shear bond strength (SBS) between cubic zirconia and two types of resin cement.

Materials and methods: Sixty cubic zirconia plates were Separated into three groups based on the pre-sintering surface treatment: Group A: air abraded using alumina particles; Group S: air abraded using silica-coated alumina particles and Group L: laser treated using Er,Cr,YSGG laser. All plates were sintered according to the manufacturer's instructions. Phosphate-containing resin cement (subgroup P) was bonded to half of the plates, while conventional composite resin cement (subgroup C) was bonded to the other half. The strength of the shear bond was determined using a universal testing machine, and the failure mode was noticed using a digital microscope.

Statistical analysis: A two-way ANOVA was utilised, followed by Tukey's post hoc test.

Results: Only surface treatment had a significant effect on bond strength (p 0.001). The highest value was found in Group A (6.680.70) Mpa, followed by Group S (4.820.73) Mpa, while the lowest value was found in Group L (0.570.08) Mpa.

Conclusions: Air abrasion of pre-sintered cubic zirconia using alumina provided the highest bond strength to both types of resin cement.

KEYWORDS: Air abrasion, Cubic zirconia, Resin cement, Shear bond strength.

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INTRODUCTION

Currently, zirconia restorations have become increasingly prevalent in the field of conservative dentistry because of their enhanced biocompatibility and superior mechanical properties. Veneered zirconia restorations reported high rates of porcelain chipping. This prompted the introduction of monolithic zirconia restorations.[1] Cubic zirconia is an exceptionally translucent type characterised by the inclusion of 8 mol% Yttria, which contributes to its superior aesthetic and mechanical qualities, including an average flexural strength of 550 Mpa. [2]

Non-etchable polycrystalline zirconia can be cemented using conventional cement. Nevertheless, resin-luting of zirconia restorations can be advocated since it improves marginal adaptation and increases retention in cases with over-tapering and short abutments or in conservative partial coverage restorations. [3] The establishment of a durable bond between resin cement and substructures becomes significant as it ensures the optimal fit of the tooth-restoration complex. Several experimental pretreatment techniques for zirconia have been proposed in the literature. These methods include air-borne particle abrasion using alumina, laser irradiation, and tribochemical silica coating. [4,5,6,7]

The question of whether surface treatment should be conducted prior to or after the sintering process remains a subject of ongoing debate among researchers. Recent research has demonstrated that pre-sintering surface treatment is an efficient and straightforward technique. Furthermore, it has been shown to enhance surface roughness and significantly reduce the proportion of the monoclinic phase, resulting from abrasion, following the sintering process. [8]

Research showed that when 10-methacryloyloxydecyl dihydrogen phosphate monomer (10-MDP)-containing resin cement was used, the organophosphate ester monomer in the MDP and the hydroxyl groups of the oxide ceramic interacted chemically. The bond was enhanced through airborne particle abrasion using alumina particles. [3]

This research sought to ascertain the impact of several surface treatments, including air abrasion and laser treatment, regarding the bond strength between ultra-translucent zirconia and both varieties of resin cement. The null hypothesis postulated That's why there is no significant impact on the shear bond strength of cubic zirconia as a result of either the surface treatment or the kind of resin cement used.

Methods:

A power analysis was designed using α=0.05, β=0.2 and an effect size (f) of (0.653) according to earlier study. [9] Minimum needed sample size (n) emerged to be 6 samples per group using G*Power version 3.1.9.7. [10]

The materials used in this study were summarised in Table 1. Sixty zirconia plates (12.5 mm in width, 12.5 mm in length, and 3.5 mm in thickness) were cut using a diamond disc mounted on an Isomet 4000 microsaw (Buehler, USA) and finished using silicon carbide paper with a grit size of 400. Plates were then Assigned to three groups based on the surface treatment (n = 20 in each).

Group (A): Air abrasion with alumina particles

Group (S): Air abrasion using silica-coated alumina particles (tribochemical silica coating).

Group (L): Laser treatment.

Zirconia plates of Group A were air-abraded with 50 μm alumina particles. The pressure applied was 2.5 bars, at a 10 mm distance, for 10 seconds, and at a 90° angle. The distance and angle of application were standardised using a custom-made holder for the nozzle. Plates of Group S were abraded using 50 μm silicated alumina particles at a pressure of 3 bar for 15 seconds. The same holding device was used. [11]

TABLE (1) Materials used in this study.

Material description	Product name	Chemical composition (Wt %)	Manufacturer	Lot number
Ultra-translucent zirconia blank Diameter 98mm Thickness 18mm	BruxZir Anterior White	ZrO_2/ HfO_2/ Y_2O_3 / Al_2O_3 (%) >99,0 Y_2O_3 5,15 %, HfO_2<3%, Al2O3 <0,5%, SiO_2<0,02%, Fe_2O_3<0,01% and Na_2O <0,04%	Prismatik Dentalcraft, Inc. USA	Z0812129
Alumina particle size 50 μm	Cobra	Precious corundum (Al_2O_3) Extremely pure – approx. 99.7% Al_2O_3.	Renfert GmbH Germany	15941205
Silicated alumina particles	Cojet	Aluminum trioxide particles coated with silica, particle size 30μm	3M ESPE Dental Products, St.paul,MN, USA	15941305
Coupling agent	Silane	Ethyl alcohol 97% and glycidoxypropyltrimethoxysilane 3%	ITENA,USA	4168-19PFXS
Conventional Composite resin cement	DUO_LINK Cement	**Base composition:** Urethane Dimethacrylate 10-30%, BisGMA 10-30%, Tetrahydrofurfuryl Methacrylate 1-5% and Trimethylolpropane Trimethacrrylate 1-5% **Catalyst composition:** Bisphenol A Diglycidylmethacrylate 10-30% and Dibenzoyl Peroxide, technically pure <1	Bisco,Inc. Schaumburg, IL60193 USA	1800000789
Phosphate-containing resin cement	THERA Cem Self adhesive resin cement	**Base composition:** Portland cement 20-50%, Ytterbium w\ Barium Glass 30-50%, Proprietary 1-10%, Ytterbium Fluoride 1-5%, BisGMA1-5% and Proprietary <1 Catalyst composition: 10-Methacryloyloxydecyl Dihydrogen Phosphate 10-30%, 2-Hydroxyethyl Methacrylate 1-5% and Tert-butyl Perbenzoate 1-5%	Bisco,Inc. Schaumburg,IL60193 USA	1800001640

Laser irradiation to Group L was performed using an Er,Cr:YSGG (erbium, chromium: yttrium, scandium, and gallium garnet) laser device (Waterlase; Biolase Technology, San Clemente, CA, USA) at power outputs of 3 W, with a 2780-nm wavelength, a pulse duration of 140 μs, and a fixed repetition rate of 50 Hz for 50 sec at a distance of 1 mm by the same operator in a sweeping motion. The laser beam was delivered by the 800-μm diameter MZ8 tip under an air/water cooling system. [12]

Surface images for one representative sample from each group were captured using a scanning electron microscope (SEM) (Inspect S, FEI Company, USA) at a magnification of 2000X. All plates were sintered using an inLab Profire sintering furnace (Dentsply Sirona, Germany), following the manufacturer's guidelines. All the samples were ultrasonically cleaned for 1 minute and then left to be dried. SEM images were captured for one sintered plate from each group.

Acrylic resin platforms were created to support the zirconia plates. Group S plates were treated with a silane coupling agent for one minute and Left to dry in the air for 10 seconds. After that, each group was divided into two subgroups based on the type of resin cement applied (n = 30 in each):

Subgroup C: Conventional resin cement

Subgroup P: 10-MDP containing resin cement.

Polyvinyl tubes with a 4 mm inner diameter and 2 mm height were utilised and bonded to zirconia plates using a bonding agent (Adper single bond 2,3M, St. Paul, USA). The bonding agent was cured for 20 seconds using a high-intensity light-emitting diode (LED) curing device (Radii Plus, SDI Dental Limited, Australia) with a light intensity of 1500 mW/cm2. Each resin cement was gradually injected into the tube until it was filled. A microbrush was used to remove the extra cement. Afterwards, the resin cement was light-cured for 30 seconds. The tubes were carefully removed to reveal the resin-cement cylinder, using a blade. Distilled water was used to preserve the samples at a temperature of 37ºC for 30 days using an incubator (Heraeus, Germany).

The shear bond strength (SBS) test was done with an Instron universal testing machine, model 3345, from England. It had a load cell of 5 KN and a cross-head speed of 0.5 mm/min. The test continued until failure occurred, and the force was measured in Newtons (N). The loads were converted to mega-pascals (MPa) by dividing the maximum failure load by the bonding area (measured in square milli-metres, mm^2). Then, each plate was examined using a digital microscope (Scope Capture Digital Micro-scope, Guangdong, China) to figure out the failure mode. The photos were acquired at a magnification of 15X. The failure modes were classified into three categories: adhesive failure, cohesive failure, and mixed adhesive/cohesive failure.

Numerical data were presented as mean and standard deviation (SD) values. A two-way ANOVA and Tukey's post hoc test were both used to analyse the normally distributed data. The significance level was set at $p > 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows*.

RESULTS

The impacts of various variables and their interactions on shear bond strength (MPa) are presented in Table 2. Only surface treatment had a significant effect on bond strength ($p<0.001$). The highest value was found in air abrasion using alumina (Group A) (6.68±0.70) Mpa, followed by tribochemical silica coating (Group S) (4.82±0.73) Mpa, while the lowest value was found in laser-treated plates (Group L) (0.57±0.08) Mpa. MDP-containing resin cement had a higher statistically non-significant value (4.05±2.69) Mpa than conventional resin cement (3.99±2.65), ($p = 0.698$).

SEM photos of Group A showed many deep and wide irregularities and grooves (Fig. 1a) that became less evident after sintering (Fig. 1b). Also, deposits of white irregular particles were found that might be remnants of alumina particles. The SEM photo of Group S showed microirregularities and porosities with deposited irregular particles (Fig. 1c). After sintering, the surface became smoother with fused irregular particles that might be silica (Fig. 1d). Group L (laser-treated) showed many prominent wide vertical and horizontal grooves (Fig. 1e) that became narrower after sintering (Fig. 1f). The digital microscopic analysis after the SBS test showed that adhesive failure was observed for all samples.

TABLE (2) Effect of different variables and their interactions on shear bond strength (MPa).

Source	Sum of Squares	df	Mean Square	f-value	p-value
Surface treatment	373.57	2	186.79	519.17	**<0.001***
Resin cement	0.05	1	0.05	0.15	**0.698ns**
Surface treatment * Resin cement	0.2	2	0.1	0.28	**0.755ns**

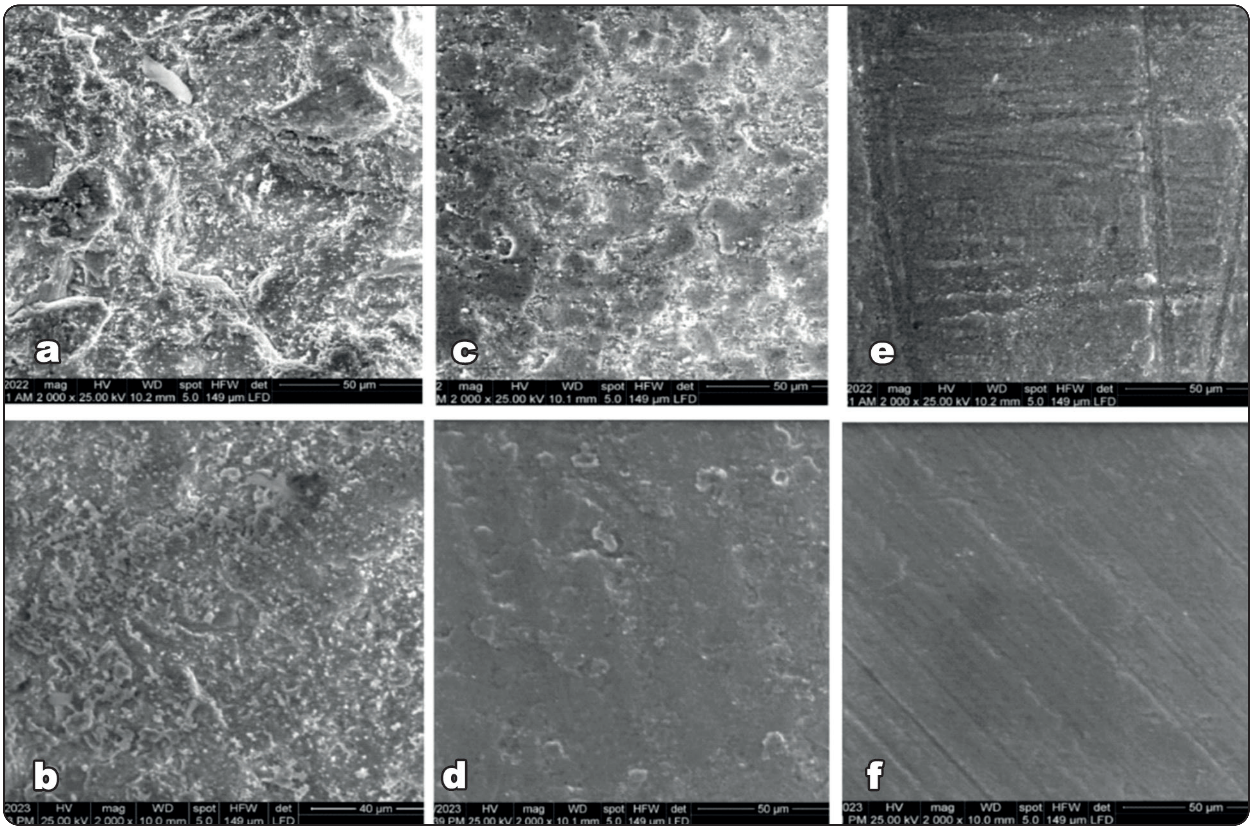

Fig (1) SEM photos of treated zirconia. a: Group A before sintering, b: Group A after sintering, c: Group S before sintering, d: Group S after sintering, e: Group L before sintering, f: Group L after sintering.

DISCUSSION

Zirconia-based restorations have diminished adhesion to resin cement in comparison to other ceramics, mostly due to their low surface energy, inadequate wettability, and lack of glass phase. Consequently, continuous investigations are carried out to determine the most effective surface treatment for zirconia ceramics. In the current study, there was a significant difference between different surface treatments. The highest value was observed in Group A, followed by Group S. This could be explained by the observations in our SEM photos, as Group A showed more microirregularities after sintering than Group S. Microirregularities promoted good micromechanical interlocking with resin cement, which resulted in the highest bond strength. These findings were supported by Petrauskas et al. [13]

The few microirregularities and deposited particles, mostly silica, in SEM photos of Group S could explain their higher bond strength than Group L. Martins et al. [8] stated that the application of silica to the ZrO_2 surfaces through silica air blasting improved the bond strength of resin cement. The applied silane coupling resulted in stable chemical bonds between the hydroxyl groups (OH) of the silica on the zirconia and the resin cement.

Unlike our study, Altan et al.[9] concluded that tribochemical silica coating of monolithic zirconia showed higher bond strength than air-abraded ones. They attributed their results to the combined mechanical and chemical bonding attained by a tribochemical silica coating. This difference in results could be attributed to the pre-sintering application of treatment in our study and the fusion of microporosities during sintering as observed in SEM photos, resulting in a smoother surface and reducing the effect of micromechanical interlocking. Our findings were supported by Ebeid et al. [14] who justified the decrease in bond strength of silica-coated zirconia in the pre-sintered stage as a result of the reduction in silica on the surface after sintering and a decrease in the overall surface roughness.

Like our study, Zanjani et al. [15] stated that the sandblasting group had better SBS than the Er,Cr:YSGG laser group. The lower bond strength of Group L demonstrated that laser irradiation could not create enough microdepth, and this resulted in limited penetration of the cement. This can be supported by the SEM photos of our study, where narrow grooves were created by laser on sintered samples. On the other hand, Akin et al. [16] and Paranhos et al. [17] have proved that Nd:YAG and Er:YAG lasers have better bond strengths than the sandblasting group. This could be attributed to the different types of laser used or its application on sintered zirconia.

Although MDP-containing resin cement demonstrated higher bond strength to zirconia than conventional resin cement, the difference was not statistically significant. Phosphoric groups in MDP produce a specific chemical reactions with hydroxyl groups of zirconia, while the decyl group in MDP inhibits water penetration at the interface between the dihydrogen phosphate and metal oxide layers. [3, 18, 19] This was confirmed by Yang et al. [20] who noticed a remarkable reduction in shear bond strength in all experimental groups after long-term artificial ageing, except for groups treated with an MDP-based zirconia primer.

On the other hand, Zhao et al. [21], de Souza et al.[22] and Salimi K et al. [23] showed no added value of incorporating MDP in resin cement on SBS values. This could be related to the concentration of MDP in the resin besides variations in the viscosities of the cement, which could influence the penetration of resin cement into the microporosities of the air-particle abraded zirconia surface.

Concerning the type of failure, Lee et al. [24] had similar results. Adhesive failure was common in the airborne particle abrasion groups and the tribochemical silica coating groups, indicating weak bonding. Further investigations are recommended to examine the long-term durability of surface treatments that have been tested and their application on sintered cubic zirconia. As surface treatments had a significant effect on the bond strength of zirconia, the null hypothesis was partially rejected.

CONCLUSIONS

The investigation's results allow for the following conclusions to be made:

- Air abrasion of pre-sintered cubic zirconia using alumina provides better bond strength to both types of resin cement, followed by tribochemical silica coating and laser treatment.
- Both conventional and phosphate-containing resin cements demonstrated nearly identical bond strengths to ultra-translucent zirconia.

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