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Effect of air-abrasive particle and universal bonding to shear bond strength of zirconia

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ABSTRACT: Background. Zirconia ceramic restoration has gained popularity in dentistry. Numerous studies were conducted to investigate the bond strength of universal bonding agents and have set reliable cementation protocols for zirconia. This study aims to determine the different effects of air-abrasive particle size and types of universal bonding agents on the shear bond strength of zirconia with dentin. **Materials and Methods.** This study used 60 samples of bar-shaped zirconia (6x4x4 mm). These samples were randomly divided into 2 groups and 30 samples. Two groups were further divided into 4 subgroups according to a combination of 2 different sizes of aluminum oxide abrasive particles (50 mm and 110 mm) and two different universal bonding agents [Single Bond Universal (SB) and All Bond Universal (AB)]. Every 4 subgroups namely AB50, AB110, SB50, and SB110 consist of 15 samples. The sample was cemented with resin adhesive cement. All samples were tested for shear bond strength with Universal Testing Machine (MPa). Data were analyzed using one-way ANOVA and Tukey's test. **Results.** There was a significant difference between AB 50 mm (AB50) group and with SB 110 mm (SB110) group ($p < 0.05$). The highest shear bond strength was the SB110 group and the lowest one was the AB50 group. **Conclusion.** The shear bond strength of zirconia to a dental substrate is affected by the combination of different air-abrasive particle sizes and types of universal bonding. Reliable cementation protocols which crucial for clinical long-term success affected by complex mechanisms and materials used.

1 INTRODUCTION

Ceramic restorations are frequently utilized in clinical practice and are rising in popularity (Goldstein et al. 2018). In recent years, zirconia restorations have been launched and have become one of the most popular dental materials (Madfa et al. 2014). The concern with zirconia as a restorative material is dislodged, fractured, or chipped due to inappropriate abutment preparation or cementation technique. Zirconia bonding concept consists of (A) air-abrasive particles, (P) zirconia primer, and (C) composite resin adhesive. Multiple researches were undertaken to discover the most effective surface treatment method and bonding protocol (Blatz et al. 2016).

Numerous producers have developed bonding solutions that are more simple, functional, and user-friendly. The universal generation is a distinct generation that exists to overcome self-etching or one-step adhesives (Sofan et al. 2017). Due to a lack of information,

numerous investigations have been done to determine the adhesion capacity of the universal bonding generation. This research on the shear bond strength test of zirconia restorations was conducted to determine the best surface treatment procedure by comparing the combination of different air-abrasive particle sizes, namely 50 mm and 110 mm (Cobra, Renfert GmbH, Hilzingen, Germany), with universal generation bonding system commonly used in Indonesia, namely Single Bond Universal (SB) (3M ESPE, USA) and All Bond Universal (AB) (Bisco, USA).

2 MATERIAL AND METHODS

Sixty samples (6 x4x4mm) of zirconia (Cercon, Dentsply, UK) densely sintered were prepared. The grinding and polishing were conducted to minimize surface irregularities before testing. The 60 zirconia samples were randomly separated into two groups based on the air-abrasive particle size (50 mm and 110 mm). Based on the combination of 2 particle sizes and 2 bonding types (SB, AB), the two groups are separated into four subgroups each with 15 samples: AB50, AB110, SB50, and SB110.

Sandblaster machine (Micra2, Dentalfarm, Italy) was used to air-abraded zirconia surface for 10 seconds, 90 angle, 1 cm far from nozzle tip and 2 bar working pressure, using 50 mm to Group AB50 & SB50 and 110 mm to Group AB110 & SB 110 (Figure 1). Vertical cut on proximal side of premolars was made to expose the dentin surface, which was subsequently polished with enhance bur with handpiece. The tooth was embedded in a 2.54 cm-diameter, 2 cm-tall polyvinyl chloride (PVC) pipe and gypsum material. The dentin was etched for 15 seconds, washed for 20 seconds, and then aerated for 2 seconds. The teeth were bonded according to the manufacturer's instructions, using All-Bond Universal (Bisco, USA) for subgroups AB50 and AB110 then Single Bond Universal (3M ESPE, USA) for subgroups SB50 and SB110. Zirconia primer (Z-Prime plus primer, Bisco, USA) was applied on the zirconia surface, left for 30 seconds then air-dried for 2 seconds (Figure 2).

The zirconia block was bonded to the tooth surface using dual cure resin cement (RelyX Ultimate, 3M, USA) and polymerized for 60 seconds, 20 seconds for each side, buccal, occlusal, and palatal. The shear bond strength test was performed in the occlusal direction at a cross-head speed of 1mm/min in a universal testing machine (Shimadzu, Japan) (Figure 3). The maximum failure load was recorded, and the shear bond strength was measured in megapascals (MPa). One-way ANOVA was performed for statistical analysis. The data showed normal distribution using the Shapiro-Wilk test. Tukey's Post Hoc test was used as a comparative test with a significance level of $p < 0.05$. All data were calculated using SPSS statistical software package (SPSS 20.0; SPSS Inc. Chicago, USA).

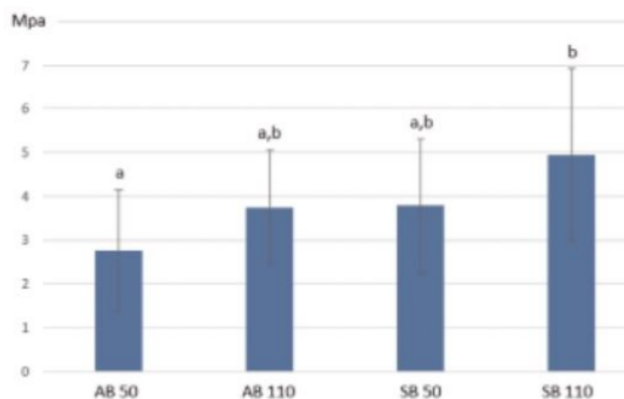


Figure 1. Chart of mean and standard deviation (MPa) of zirconia shear bonding strength and dentin. Only group a (AB50) and group b (SB110) showed significant differences.

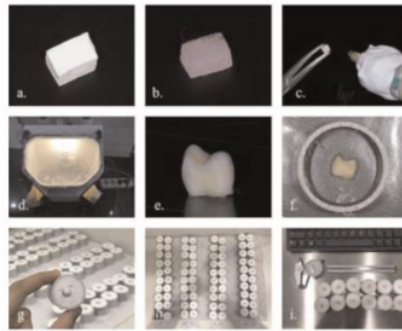


Figure 2. (a) Zirconia block prior to sintering. (b) Zirconia block after being sintered, shrunk from 18% to 20%. (c) Zirconia was air-abraded with Alumina Oxide powder. (d) Sandblaster unit device. (e) Premolar proximal and cervical preparation. (f) The tooth sample was placed in a cylindrical PVC tube. (g) Post-cemented zirconia on dentin. (h) 60 samples in the overall sample group. (i) Zirconia sample measurement before placement on the Universal Testing Machine.

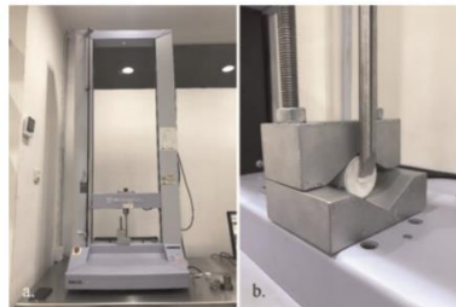


Figure 3. (a) Universal Testing Machine (Shimadzu, Japan) (b) Research sample was rested on the jig of the Universal Testing Machine (Shimadzu, Japan).

3 RESULTS

At the Laboratory of Dental Materials and Testing Center of Research and Education (DMT Core), Faculty of Dentistry, Universitas Trisakti, research has been conducted on the different impacts of combination air-abrasive particle size and universal bonding system on the shear bond strength of zirconia using universal testing machine (Shimadzu, Japan). The SB110 group has the highest average shear strength at 4.95 1.05 Mpa, while the lowest average shear strength was 2.75 1.37 MPa for the AB50 group (Table 1). The data were normally distributed according to the Shapiro-Wilk test ($p > 0,05$). Homogeneous data in

Table 1. Results mean and standard deviation of dentin and zirconia Shear Bonding Strength (MPa).

Sample Group	n	Mean \pm Standard Deviation
50 μ m particles		
<i>All Bond Universal</i>	15	2,76 \pm 1,39
<i>Single Bond Universal</i>	15	3,75 \pm 1,30
110 μ m particles		
<i>All Bond Universal</i>	15	3,78 \pm 1,53
<i>Single Bond Universal</i>	15	4,95 \pm 1,96

each group was performed by the Levene test ($p > 0,05$). The data were analyzed by One Way ANOVA showed that there was a significant difference between these groups. The test was continued with Tukey Post Hoc Test was found that significant differences existed only between AB 50 mm (AB50) group with SB 110 mm (SB110) group by Tukey Post Hoc Test ($p < 0,05$) (Table 2).

Table 2. Differences in the effect of air-abrasive particle size and universal bonding generation on zirconia shear bond strength tested by the Tukey test.

Main group	Comparison group	p value
<i>All Bond Universal</i> + Particle size 50 μm	<i>Single Bond Universal</i> + Particle size 110 μm	0,002*
	<i>All Bond Universal</i> + Particle size 110 μm	0,291
	<i>Single Bond Universal</i> + Particle size 50 μm	0,313
<i>Single Bond Universal</i> + Particle size 50 μm	<i>Single Bond Universal</i> + Particle size 110 μm	0,180
	<i>All Bond Universal</i> + Particle size 110 μm	1,000
<i>All Bond Universal</i> + Particle size 110 μm	<i>Single Bond Universal</i> + Particle size 110 μm	0,183

* sig $p < 0,05$ | n = 15

4 DISCUSSION

Zirconia is a natural tooth-colored material that is compatible with gingival tissue. The long-term success of zirconia is depending on the preparation procedure, impacting the intaglio layer, bond strength, and durability between zirconia and cementation material (Madfa et al. 2014). Cementation is one of the most essential phases in assuring the longevity and continuity of a restoration. To optimize the bond strength of zirconia restorations, the air-abrasive or sandblasting system process is one of the crucial steps and treatments of the tooth surface with etching and bonding (Blatz et al. 2016; Melo & Souza 2015).

According to the one-way ANOVA test, there is a significant difference in shear bond strength (MPa) between the treatment groups, distinguishing the effect of the combination of air-abrasive particle size and two types of universal generation bonding on the shear bond strength of zirconia to teeth. When the Post Hoc Test was conducted with the Tukey test, only the AB50–SB110 pair was statistically different, but the other pairings, AB 50–SB 50, AB 110, and SB 110, were not significantly different. The considerable variation that occurs solely in the AB50–SB110 group may be caused by a variety of reasons, including variances in the bonding material content, the influence of roughness generated by abrasive air-particles, and other factors (Su et al. 2015; Tanış et al. 2015).

The SB group with a combination of 110 mm air-abrasive particles had the highest average shear bond strength for zirconia treated with air-abrasive particles and a universal bonding system, measuring 4.95 1.96 MPa. This may be related to different compositions of Single Bond Universal and AB. SB contains silane, filler, and copolymer, whereas AB has not. According to reports, fillers enhanced mechanical qualities, reduced polymerization shrinkage, and lowered linear coefficient of thermal expansion which contributed to an increase in bond strength (Fanning et al. 1995). Silane increases surface free energy and wettability as a result improves initial bond strength (Kim et al. 2015). Methacrylate functional copolymer increases the stabilization of adhesive bonding and mitigates the negative effects of humidity. SB materials exhibit a degree of conversion of physical properties, with hydrophilic properties predominating prior to curing and during the application, while hydrophobic properties predominate post-drying, during processing, and after curing in order to increase the long-term bonding strength (Yang et al. 2018).

The group AB with a combination of 50 mm air-abrasive particles and a shear bond strength of 2,759 1,378 MPa had the lowest average shear bond strength. This suggests that powder particles that are smaller and finer are more abrasive (Souza et al. 2013). However, the study conducted using particle sizes of 50 mm and 30 mm showed that small particles of 30 mm with a strength of 2.5 bar (medium) for 20 seconds were a more effective strategy for protecting restorative materials (Su et al. 2015).

The impact of the erosive material from the water-abrasive particles makes the surface rough, and clean, and increases the surface's wettability; however, this procedure can also create micro-defects and cracks; consequently, the firing strength of the powder particles, the distance between the nozzle tips and the zirconia, and particle size must be adjusted (Larsson 2014; Martins et al. 2019). Numerous variables, such as the orientation of the nozzle tip, the exposure duration to sandblasting, the flow rate of the powder stream deployed, and the pressure movement of the operator, contribute to the widely differing research outcomes. The operator should always reposition the tip of the nozzle to prevent localized blazing, which could cause damage to zirconia coating or other ceramic material. Modifications in the cementation method can affect the restoration's stability differently. There is a complex interrelationship between air-abrasive particles, the zirconia surface, and tooth-bonding adhesives (Guazzato et al. 2005; Kim et al. 2005; Saleh et al. 2019).

The structure of the dentin substrate makes ideal bonding strength difficult to achieve. Enamel is composed of 95% hydroxyapatite and has a regular structure, whereas dentin only contains 50% hydroxyapatite by volume and has an uneven structure. Dentin is made of tubules containing the pulp processes of the odontoblasts, making this structure susceptible and dynamically changing in response to age, caries, and dental operations. Fluid in the tubules might flow from the pulp to the external part, thereby reducing the adherence of the composite resin (Garg & Garg 2015; Ritter et al. 2019).

Bonding strength with dentin is affected by the bonding system's strategy, the dentin's dry-wet condition, and the bonding's pH level. By dissolving the dentin minerals, including the smear layer, with acid, the etch-and-rinse process could increase bond strength as well. The application of adhesives containing monomers infiltrates and displaces water between collagen fibrils. Following polymerization, a hybrid layer composed of resin tags and dentinal tubules is formed, resulting in micromechanical retention. Universal bonding stability was achieved as a result of the MDP monomer forming a stable nanolayer with less solubility that precipitated MDP-calcium deposits on the interfacial bond (Marchesi et al. 2014; Perdigao & Loguercio 2014; Van et al. 2003).

5 CONCLUSION

Reliable cementation methods, which are critical for long-term clinical success, are affected by the complex mechanism and material used. The shear bond strength of zirconia to the dental surface is affected by the combination of air abrasive particle size and type of the Universal Bonding Agent. This study suggests the use of combination of 10 mm air abrasive particles for zirconia surface treatment and SB as adhesive bonding for zirconia cementation protocols.

2 CONFLICT OF INTEREST

There are no conflicts of interest to declare by the authors. All co-authors have read and approved the article, and there are no financial conflicts of interest to disclose. ACKNOWLEDGEMENT This work would not have been possible without the assistance of my lecturers in the Postgraduate Program of Conservative Dentistry at Universitas Trisakti's Faculty of Dentistry. I would like to thank them for their support and advice, which significantly enhanced this paper.

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