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Effects of alumina-blasting pressure on the bonding to super/ultra-translucent zirconia

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ABSTRACT

Objectives. Translucent zirconia has brought the advantages such as less tooth preparation, biological compatibility, high strength, good mechanical properties, and less antagonist wear. This study's aim was to elucidate how clinically relevant surface treatments; alumina-abrasion and priming effect on bond strength of Y-PSZ in three different translucency grades after long-term water storage.

Materials and Methods. Three highly translucent Y-PSZ grades were ground flat with #600-grit SiC paper. Four different surface treatments (untreated, alumina blasting at 0.1 MPa or 0.2 MPa or 0.4 MPa) and two resin cements (PANAVIA V5 and PANAVIA SA CEMENT PLUS AUTOMIX) were tested. The bonded specimens were stored in water for 1 day, 30 days and 150 days and tensile bond strength (TBS) were measured with universal testing machine at a crosshead speed of 2 mm/min (n=10). The surface roughness (Sa) measurement and surface morphology analysis without alumina-blasting pressure (untreated) and with alumina-blasting pressures (0.1 MPa, 0.2 MPa and 0.4 MPa) for three different zirconia grades were evaluated with 3D-Laser Scanning Confocal Microscope.

Results. Different alumina-blasting pressures and different storage periods affected the bonding of resin cement to translucent zirconia. The Weibull moduli increased in some groups after 150 days storage. After 1 day and 30 days storage, 0.4 MPa alumina-blasting pressure provided superior bond strength, however, after 150 days, 0.2 MPa gave reliable and stable bond strength.

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Significance. Alumina-blasting pressure of 0.2 MPa was the most effective for reliable and durable bonding performance to translucent zirconia after long-term water storage.

1. Introduction

Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is the toughest ceramic restorative material in dentistry. However, esthetics and in particular in terms of translucency are considered a shortcoming for this type of zirconia. Its opacity becomes a problem especially when placing an anterior crown or short-span fixed dental prosthesis adjacent to other anterior natural teeth [1–4]. A restoration should match the natural tooth in terms of shade, shape, size, surface texture and translucency to be considered esthetically pleasing [5].

The amount of yttrium oxide stabilizer of yttria-partially stabilized zirconia (Y-PSZ) was focused in an effort to fully stabilize the material and enhance its optical properties to optimize the characteristics of full-contour monolithic restorations. There has been a large volume of literature concerning the translucency of the developed Y-PSZ [6–11]. The first generation of translucent zirconia was based on conventional Y-TZP ceramic, which presented high opacity, high resistance, toughness and enhanced mechanical properties. The second generation also consisted of Y-TZP with a decrease in the zirconia's grain size; this small change in the materials composition enhanced light transmission and optical/aesthetic properties, maintaining their smart characteristics [12]. The third generation had the important change of increasing the percentage of yttrium oxide stabilizer (>3 mol%), which resulted in significant amount of cubic zirconia phase [13]. The optical/esthetic properties were improved, although it was expected that the mechanical properties would be somewhat compromised.

Previously, another significant drawback of zirconia ceramic was limited adhesion to resin cements and therefore, tooth structure because since the substrate was composed of glass-free polycrystalline microstructure. Traditional silane coupling agents used in with silica-based ceramics and hydrofluoric acid etching do not work effectively with zirconia due to the lack of silica in zirconia ceramics [14].

10-Methacryloyloxydecyl dihydrogen phosphate (10-MDP) was a phosphoric acid methacrylate adhesive monomer originally developed to bond to tooth structure and metal oxide restorative material. Research has shown that 10-MDP promotes adhesion to zirconia; Tanis and Akcaboy et al. reported that use of 10-MDP monomer containing resin cement increased the bond strength of sandblasted zirconia [15]. Byeon et al. proved that the application of 10-MDP-based primers after Al2O3 sandblasting enhanced the resin bond strength to Y-TZP [16]. However, influence of alumina-abrasion on zirconia is controversial. Some papers reported decreased strength after sandblasting [17–19], whereas the others reported increased strength. Particularly, the Y-PSZ presented inferior mechanical behavior in comparison to the conventional Y-TZP [20]. To date, only few studies have reported on the influence of surface treatments on highly translucent zirconia [21–23].

In order to find out suitable surface treatment to enhance bonding durability of highly translucent zirconia ceramic restorations, we investigated the effect of various surface conditioning methods, i.e., alumina-sandblasting and priming, on the long-term resin bond strength to translucent zirconia ceramic. The purpose of this study was to evaluate the bond strength and surface roughness of super-translucent and ultra-translucent zirconia ceramics with different alumina-sandblasting pressures. The null hypotheses tested were that there is no influence of alumina-sandblasting pressure on resin–Y-PSZ zirconia ceramic bond durability (1) when different alumina-sandblasting pressures are applied and (2) when different resin cement systems are used.

2. Materials and methods

The materials used in this study are listed in Table 1. Industrially manufactured discs from fully sintered zirconia ceramics KATANA Zirconia HT, KATANA Zirconia ST and KATANA Zirconia UT (all from Kuraray Noritake Dental, Tokyo, Japan) were used.

2.1. *Specimen preparation*

Specimen preparations for tensile bond strength (TBS) test are summarized in Fig. 1. A total of 720 fully sintered specimens from three different Y-PSZ grades (240HT, 240 ST and 240 UT) are provided by the manufacturer in the form of 5 mm-thickness and 12 mm-diameter. The bonding surfaces of the disks were polished with 600-grit silicon carbide papers under running water to mimic the manufactured surface. Before cementation, the Y-PSZ blocks were sandblasted at 0 MPa (UN), 0.1 MPa (P1), 0.2 MPa (P2) and 0.4 MPa (P4) pressure with 50 μm Al_2O_3 particles (Kulzer, GmbH, Germany) for 20 s at an operating distance of 10 mm with a sandblaster (Renfert Basic eco, Renfert GmbH, Germany).

2.2. *Surface roughness analysis*

To investigate the surface features of the tested specimens of three different translucent zirconia grades without alumina-sandblasting pressure (UN) and with alumina-sandblasting pressures (P1, P2 and P4), 5 specimens were selected from each group. All specimens were ultrasonically cleaned in deionized water for 5 min and in 99% ethanol for 2 min A 3D-Laser Scanning Confocal Microscope (KEYENCE VK-X 150/160, Osaka, Japan) was used to evaluate 3D surface morphology and measure the surface roughness (Sa) of the tested specimens using an observation software (VK-H1XV2E, KEYENCE).

Table 1 – Materials used in this study.

Material	Composition	Manufacture	Batch number
KATANA Zirconia HT	90–95% ZrO_2, 5–8% Y_2O_3, Other <2%	Kuraray Noritake Dental	W214I04
KATANA Zirconia ST	88–93%ZrO_2, 7–10%Y_2 O_3, Other<2%	Kuraray Noritake Dental	55W17J05
KATANA Zirconia UT	87–92%ZrO_2, 8–11%Y_2O_3, Other<2%	Kuraray Noritake Dental	60W17GD5
Clearfil Ceramic Primer Plus (CP)	Ethanol, [a]γ-MPTS, [b]10-MDP	Kuraray Noritake Dental	B90031
PANAVIA V5 (V5)	Paste A: [c]Bis-GMA, [d]TEGDMA, hydrophobic aromatic dimethacrylate, hydrophilic aliphatic dimethacrylate, initiators, accelerators, silanated barium glass filler, silanated fluoroalminosilicate glass filler, colloidal silica Paste B: Bis-GMA, hydrophobic aromatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, silanated alminium oxide filler, accelerators, dl-Camphorquinone, pigments	Kuraray Noritake Dental	BF0042
PANAVIA SA CEMENT PLUS AUTOMIX (SA)	Paste A: 10-MDP, Bis-GMA, TEGDMA, hydrophobic aromatic dimethacrylate, [e]HEMA, silanated barium glass filler, silanated colloidal silica, dl Camphorquinone, peroxide, catalysts, pigments Paste B: hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, silanated barium glass filler, surface treated sodium fluoride, accelerators, pigments	Kuraray Noritake Dental	AQ0203
Alloy primer (AP)	Acetone, 10-MDP, [f]VBATDT	Kuraray Noritake Dental	A40077

[a] γ-MPTS; 3-trimethoxysilylpropyl methacrylate.
[b] 10-MDP; 10-methacryloyloxydecyl dihydrogen phosphate.
[c] Bis-GMA; Bisphenol A di (2-hydroxy propoxy) dimethacrylate.
[d] TEGDMA; Triethylene glycol methacrylate.
[e] HEMA; 2-Hydroxyethyl methacrylate.
[f] VBATDT; 6-(4-vinylbenzyl-*n*-propyl) amino-1,3,5-triazine-2,4-dithione.

2.3. *TBS test*

After the surface treatment protocol, all specimens were ultrasonically cleaned in deionized water for 5 min and in 99% ethanol for 2 min A piece of aluminum tape with a circular hole (4 mm in diameter and 100 μm in thickness) was placed on the polished surface to demarcate the bonding area. In SA groups, a 10-MDP containing dual-cured self-adhesive resin cement (PANAVIA SA CEMENT PLUS AUTOMIX, Kuraray Noritake Dental) was applied directly to the treated surface to form a handle using a metal primer-treated stainless steel rod for subsequent TBS testing. The specimens were then light-cured with a halogen light (Optilux 501, 600 mW/cm^2, Demetron, Danbury, CT, USA) from all quarters for 10 s, left at room temperature for 30 min, and then stored in water for 24 h (1 d), 30 days (30 d) or 150 days (150 d) at 37 °C water. Similar cementation procedure was taken in PANAVIA V5 (Kuraray Noritake Dental) groups, however, prior to cementation, Clearfil Ceramic Primer Plus (CP) (Kuraray Noritake Dental, Tokyo, Japan) was applied to the surface of the specimens.

Tensile bond strengths were measured using a universal testing machine (Autograph AGS-J, Shimadzu, Kyoto, Japan) at a crosshead speed of 2 mm/min. Failure mode was examined under light microscope (Nikon SMZ 1000, Nikon Corp, Tokyo Japan) at a magnification of 8× and classified into the following two categories; mixed adhesive failure: resin cement partly on the zirconia ceramics and partly on metal rods and cohesive failure: failure within resin cement.

2.4. *Statistical analysis*

The TBS results were statistically analyzed using Weibull analysis; pivotal confidence bounds were calculated using Monte Carlo simulation. Different groups were compared at the B63.2 unreliability level, being considered as the actual bonding effectiveness. All tests were performed at a significance level of $\alpha = 0.05$ using a software package (R3.4.3 and abrem package, R Foundation for Statistical Computing, Vienna, Austria). The mean and standard deviation of the results of surface roughness were collected and statistically analyzed with 2-way ANOVA and t-test with Bonferroni Correction ($\alpha = 0.05$) using statistical software (SPSS 22, IBM; Armonk, NY, USA).

3. Results

Table 2 and 3 summarize the results of Weibull analysis for all groups and lists the percentage of ‘cohesive’ failure as well. Representative Weibull plots of 150 d groups are presented in Fig. 2. After 150 d water storage, Weibull moduli of all of the tested groups increased for V5 groups except HT-P2 groups, whereas in SA groups, some showed raising in Weibull moduli.

For HT groups, all HT groups represented increasing in Weibull moduli except HT-V5-P2 after 150 d water storage. After 150 d water storage, Weibull modulus of 14.6 was the highest at V5-P4 group with bond strength of 28.7 MPa.

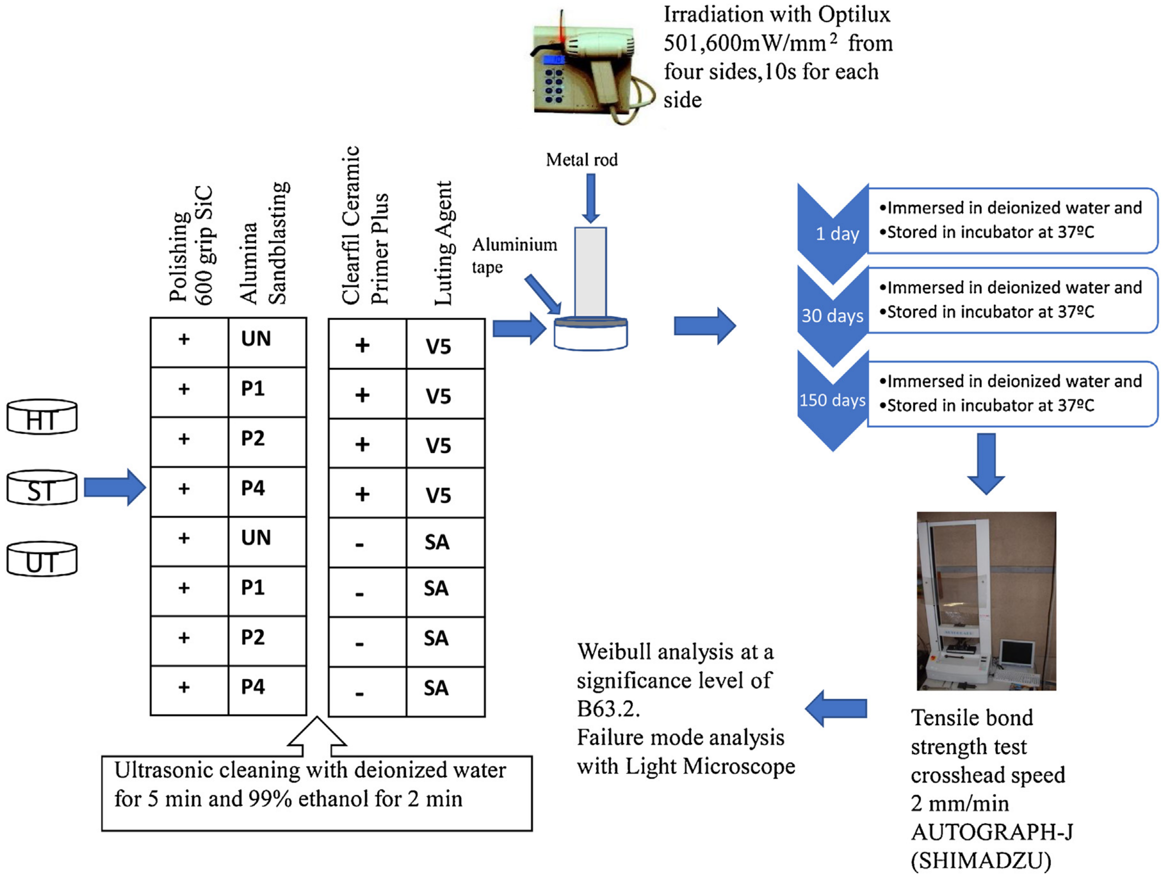

Fig. 1 – Schematic illustration of the methodology of specimen preparation for tensile bond strength.

For ST groups, among ST-V5 groups, 0.2 MPa after 150 d provided highest Weibull modulus of 28.6 with 31.2 MPa. Among ST-SA groups, Weibull modulus of 8.6 at 0.2 MPa showed highest with bond strength of 29.8 MPa after 150 d.

For UT groups, all of UT groups increased in Weibull moduli except UT-SA-UN group after 150 d water storage while UT-V5-UN showed the highest modulus of 16.6 with bond strength of 17.0 MPa.

Most of the specimens of the tested groups failed 'cohesively' in the resin cement under light microscope. Based on failure mode analysis, some groups occasionally failed in mix types; at microscopic level, remnants of resin cement were found to be attached to the zirconia surface and metal rod. After 150 d, both V5 groups and SA groups showed all cohesive failure.

Fig. 3 shows 3D surface morphology and Table 4 provides Sa values of tested specimens. Among all groups, Sa value of UT at a pressure of 0.4 MPa was the highest and UN groups showed the same value for all three different translucent zirconia.

Table 4 – Mean values and standard deviations of surface roughness (Sa, μm).

	UN	P1	P2	P4
HT	5.3 ± 0.4^{a}	5.7 ± 0.2^{a}	10.8 ± 0.6^{A}	$12.3 \pm 0.4^{C, D}$
ST	5.3 ± 0.4^{b}	5.5 ± 0.5^{b}	10.9 ± 0.9^{B}	14.1 ± 0.9^{C}
UT	5.3 ± 0.2^{c}	5.9 ± 0.4^{c}	$12.5 \pm 0.4^{A, B}$	15.1 ± 1.2^{D}

n = 5.
Data are shown as mean ± standard deviation.
Same small superscript letters indicate no statistically significant difference among the alumina-blasting pressures ($p > 0.05$).
Same large superscript letters indicate statistically significant difference between translucency ($p < 0.05$).

4. Discussion

Without alumina-sandblasting, using only 10-MDP containing resin cement or primer did not provide reliable TBS. Alumina-sandblasting at 0.1 MPa enhanced short-term TBS durability, however, declined significantly after 150 d water storage. For V5 groups, 0.4 MPa pressure of 1 d and 30 d water storage gave the highest TBS when compared to any other pressures tested. For SA groups, no difference in TBS at 0.2 MPa and 0.4 MPa for 1 d and 30 d water storage. After long-term water storage, 0.2 MPa alumina-sandblasting pressure provided reliable bond strength although 0.4 MPa pressure enhanced bond strength and superior than others during short-term water storage. The findings of this study required rejection of the first null hypothesis that "there is no influence of alumina-blasting pressures on resin–Y-PSZ zirconia ceramic bond durability when different alumina-blasting pressures are applied". However, the bond strength did not show the difference when different resin cement systems are used. Thus, the second hypothesis, "bond durability to resin–Y-PSZ zirconia ceramic

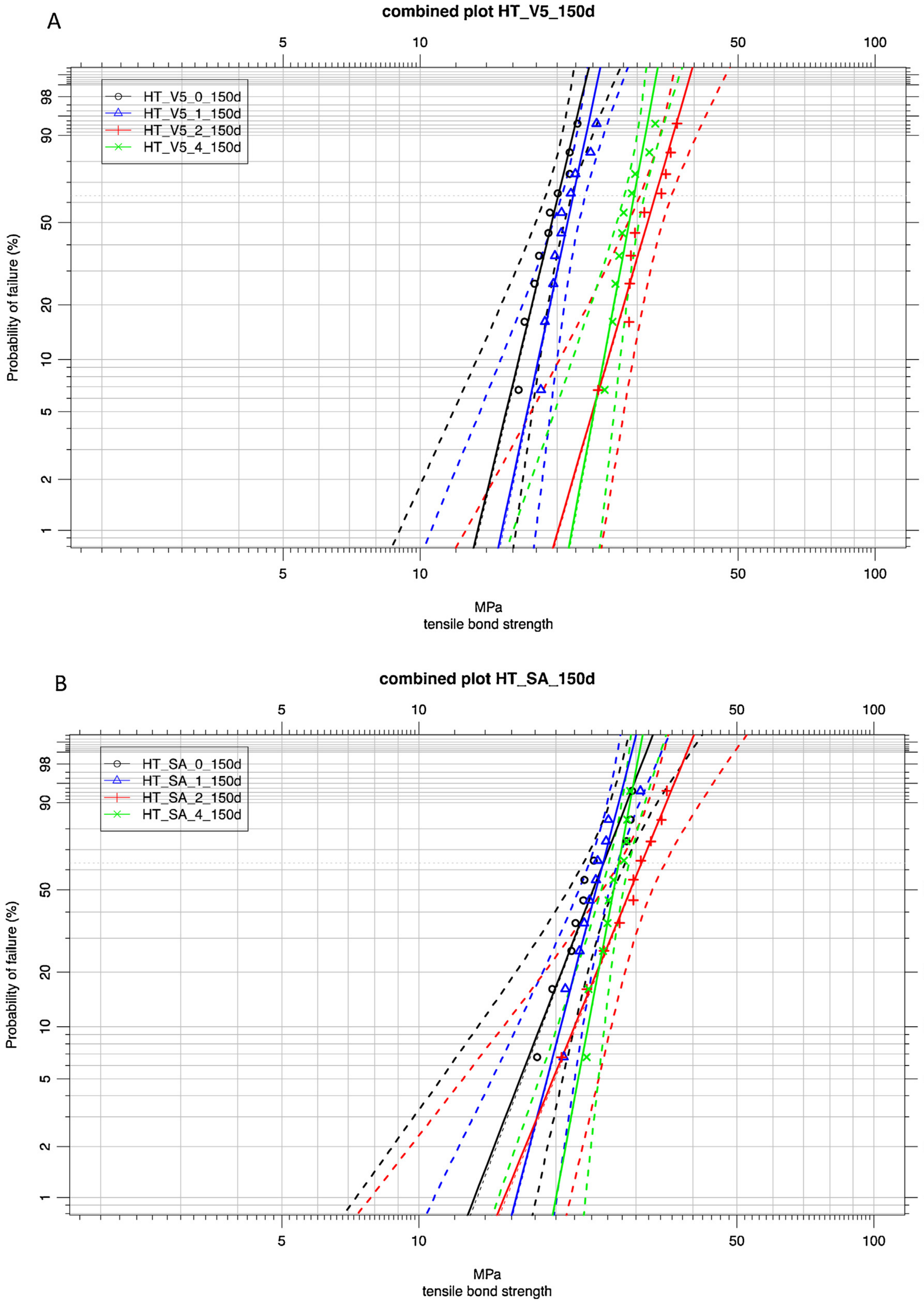

Fig. 2 – Illustration of the Weibull plots of the 150 d of HT of V5 and SA groups (2A-2B).

Table 2 – The results of Weibull analysis and the failure mode of V5 group.

Translucency	Pressure	Storage	Shape (modulus)[a]	Scale (B63.2)[b]	95%Confidence level at B63.2[c]	Percentage of failure[d]
HT	UN	1 d	6.6	28.4	24.9–31.8	100
		30 d	8.0	24.6	22.1–27.1	50
		150 d	11.3	19.4	17.9–20.7	100
	0.1 MPa	1 d	4.3	31.7	25.7–37.6	90
		30 d	5.1	26.6	22.3–30.8	100
		150 d	12.8	21.0	19.6–22.3	100
	0.2 MPa	1 d	11.1	35.6	33.0–38.2	100
		30 d	8.3	33.1	29.9–36.3	100
		150 d	9.4	31.4	28.6–34.1	100
	0.4 MPa	1 d	4.9	41.2	34.6–47.8	90
		30 d	7.4	35.5	31.6–39.3	80
		150 d	14.6	28.7	27.1–30.2	100
ST	UN	1 d	3.6	28.1	19.6–31.1	100
		30 d	7.7	25.7	21.8–26.8	90
		150 d	8.1	17.5	15.0–18.3	100
	0.1 MPa	1 d	6.3	31.4	25.7–33.3	100
		30 d	5.5	27.4	21.6–29.0	100
		150 d	11.3	19.9	17.8–20.5	100
	0.2 MPa	1 d	7.4	40.1	33.6–42.0	80
		30 d	6.7	36.0	29.7–38.0	100
		150 d	28.6	31.2	29.9–31.6	100
	0.4 MPa	1 d	5.7	40.8	32.4–43.3	100
		30 d	9.0	37.6	32.7–39.1	50
		150 d	11.8	27.5	24.6–28.4	100
UT	UN	1 d	3.8	29.9	21.1–32.7	80
		30 d	10.4	23.1	20.4–23.8	100
		150 d	16.6	17.0	15.8–17.4	100
	0.1 MPa	1 d	5.7	28.7	22.9–30.5	90
		30 d	4.6	27.4	20.8–29.6	100
		150 d	12.1	18.7	16.8–19.3	100
	0.2 MPa	1 d	5.2	30.8	24.2–33.0	100
		30 d	8.1	32.6	27.9–34.1	70
		150 d	13.6	31.6	28.7–32.4	100
	0.4 MPa	1 d	4.44	39.8	29.8–43.0	100
		30 d	4.4	36.6	27.4–39.6	50
		150 d	9.1	26.6	23.1–27.7	100

N = 10 for each group.

[a] The higher the Weibull shape, the more reliable the treatment.

[b] The higher the Weibull scale, the higher the bonding effectiveness.

[c] Statistically non-significant group at B63.2.

[d] The rest percentage represents the area percentage of 'mixed' failure in the resin cement.

is not influenced by different resin cement systems" is acceptable.

From the current results, TBS of all V5 groups increased in accordance with increasing in pressure for short-term water storage conditions (1 d and 30 d) but SA groups did not vary with pressures. In general, increasing in pressures results in the increased surface roughness and bonding surface area, which enhance the wettability of adhesives and promote bond strength. In case of V5, this effect was not observed; the possible cause was that the applied primer before cementation made the surface defect caused by alumina-abrasion less and enhanced bond strength. After 150 d, there was no difference in bond strength of V5 groups and SA groups in term of pressures.

From overall results of this study, 0.2 MPa provided the most stable bond strength to three different Y-PSZ zirconia grades. The translucency of three different Y-PSZ zirconia grades had no effect on TBS. Agreeably, Kwon et al. proved that both short- and long-term bond strength of UT were similar to that of HT and lithium disilicate under 0.2 MPa alumina abrasion pressure in spite of low flexural strength [24]. However, Sa values varied in term of translucency of zirconia under different pressures, which reflects different response of the surfaces among various zirconia to the same blasting pressure. Among all tested groups, UN and P1 showed no difference in Sa value for HT, ST and UT but P2 and P4 increased in Sa value with decreased in translucency. The Sa value of UT at a pressure of 0.4 MPa was highest among the tested groups.

In the present study, the result was that the more translucent the zirconia is, the more aggressive the surface roughness under increasing alumina-sandblasting pressures. Pereira et al. reported that UT had larger grain size and after applying alumina-abrasion, the grains in zirconia were pulled out [20]. The bigger the grain size was pulled out, the greater the surface defect was caused which subsequently provided the surface roughness more.

The bond-strength data were in line with the fracture-analysis data. The current study showed cohesive failures

Table 3 – The results of Weibull analysis and the failure mode of SA group.

Translucency	Pressure	Storage	Shape (modulus)[a]	Scale (B63.2)[b]	95%Confidence level at B63.2[c]	Percentage of failure[d]
HT	UN	1 d	4.8	29.5	22.7–31.9	70
		30 d	4.0	26.5	19.3–29.2	40
		150 d	7.1	25.4	21.2–26.8	100
	0.1 MPa	1 d	8.6	36.4	31.5–37.9	80
		30 d	3.9	35.6	25.7–39.1	100
		150 d	10.5	25.4	22.5–26.3	100
	0.2 MPa	1 d	4.9	40.2	30.9–43.4	100
		30 d	7.4	35.9	30.2–37.6	20
		150 d	6.6	30.8	25.4–32.6	100
	0.4 MPa	1 d	5.7	37.3	29.7–39.7	90
		30 d	4.2	39.0	28.6–42.4	100
		150 d	14.5	27.5	25.2–28.2	100
ST	UN	1 d	5.2	29.9	23.2–32.0	100
		30 d	4.6	27.1	20.5–29.3	100
		150 d	6.0	23.8	19.2–25.3	100
	0.1 MPa	1 d	10.1	37.7	33.3–39.0	100
		30 d	4.7	42.4	32.1–45.6	70
		150 d	5.4	27.1	21.5–28.8	100
	0.2 MPa	1 d	4.5	40.1	30.1–43.4	100
		30 d	6.6	35.1	29.0–37.1	100
		150 d	8.6	29.8	25.7–31.1	100
	0.4 MPa	1 d	3.8	37.1	26.5–40.9	100
		30 d	5.1	40.7	31.7–43.6	100
		150 d	7.8	31.5	26.8–32.8	100
UT	UN	1 d	5.3	32.5	25.5–34.7	60
		30 d	6.2	26.9	21.9–28.5	100
		150 d	6.0	21.9	17.7–23.2	100
	0.1 MPa	1 d	5.9	35.5	28.6–37.6	80
		30 d	4.4	39.1	29.2–42.4	50
		150 d	7.7	25.7	21.7–26.9	100
	0.2 MPa	1 d	4.3	38.8	28.6–42.4	100
		30 d	7.4	34.6	29.1–36.3	100
		150 d	8.0	30.4	25.9–31.8	100
	0.4 MPa	1 d	6.1	34.7	28.1–36.6	70
		30 d	5.8	33.3	26.6–35.4	100
		150 d	11.7	29.2	26.2–30.1	100

N = 10 for each group.

[a] The higher the Weibull shape, the more reliable the treatment.

[b] The higher the Weibull scale, the higher the bonding effectiveness.

[c] Statistically non-significant group at B63.2.

[d] The rest percentage represents the area percentage of ‘mixed’ failure in the resin cement.

predominantly. After 150 d, all groups showed cohesive failure. It may be due to accumulation of 10-MDP on the zirconia surface, along with improved adhesion and degree of conversion of resin cement [25]. During water storage, 10-MDP that could accumulate after primer application and air drying may have dissolved into and polymerized with the dimethacrylate monomers in the resin cement [26].

The TBS without sandblasting did not show pre-testing failure even after 150 d water storage. This corroborates with the observation that 10-MDP containing primer or 10-MDP containing self-adhesive resin cement effectively bonded to polished, but not alumina-blasted, zirconia. Controversially, Yang et al. suggested that the bond strength decreased to 0 MPa even using 10-MDP containing Alloy Primer or Clearfil Ceramic Primer [27], while others reported bond strength values and lower contact angles to mirror-polished zirconia surfaces using 10-MDP containing monomer [28].

Collectively, it is obvious that sandblasted rough zirconia surface makes an important contribution to bonding with 10-MDP based resin. A previous study indicated that in order to achieve superior bond strength between an indirect composite resin and the Y-TZP zirconia core, the sandblasting pressure should be $\geq$0.2 MPa [29] to promote micromechanical interlocking of resin to the surface. However, after 150 d water storage, the TBS of all the groups were unstable and drastically decreased except for the groups sandblasted at pressure of 0.2 MPa. It appears that 0.4 MPa pressure could cause excessive abrasion and mechanical stress on the zirconia surface and generated surface defects which might compromise the strength of zirconia that result in the failure of zirconia bonding.

Kern et al. suggested reducing the pressure during sandblasting can be advantageous in reducing the negative surface effects caused by sandblasting [30]. In several studies on Y-TZP zirconia ceramic bonding, sandblasting with 50 μm Al_2O_3 at 0.25 MPa at 10 mm operation distance has been used to condition the ceramic surface in order to increase the surface

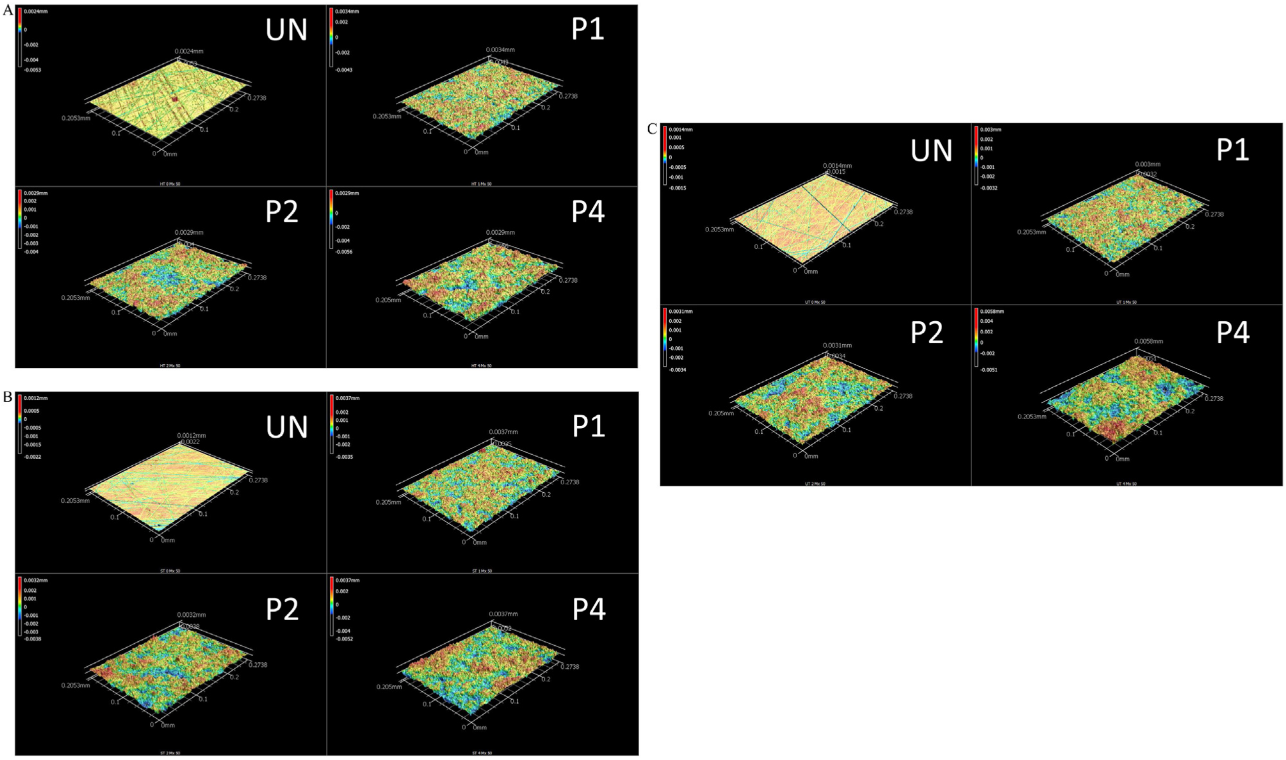

Fig. 3 – (A) Laser scanning confocal microscope 3D topography images of the HT zirconia surface showing untreated (UN) and alumina blasted (P1, P2 and P4). (B) Laser scanning confocal microscope 3D topography images of the ST zirconia surface showing untreated (UN) and alumina blasted (P1, P2 and P4). (C) Laser scanning confocal microscope 3D topography images of the UT zirconia surface showing untreated (UN) and alumina blasted (P1, P2 and P4).

roughness as well as to activate the surface to enhance bond strength [31–34].

Resin cements are recommended for adhesive cementation because of their low solubility in the oral environment, reduced microleakage at the restoration-tooth interface, good optical properties, and low incidence of marginal staining and recurrent caries [35–40]. Self-adhesive cements represent the latest and most simplified category of resin cements, which rapidly gained popularity to lute all ceramic restorations as a result of their ease of use. While the use of resin cements with separate primers has shown more promising results for bonding to dentin and lithium disilicate ceramic [41]. Miragaya et al., found that irrespective of the surface treatment, the self-adhesive resin cements performed better in terms of bond strength to zirconia ceramic than a conventional resin cement [42]. The result of the present study demonstrated that there was no difference in TBS for V5 and SA after 150 d water storage. We attributed this to the presence of 10-MDP in both V5 primer (CP) and SA compositions. Zirconia surface is easily covered with a passive oxide layer which makes zirconia similar to metals [43]. Therefore, it can be used for increasing bond strength between zirconia and resin cements.

Long-term storage is often used as the artificial aging methods in vitro bonding testing in which oral conditions can have effects on the durability of the resin bond strength to zirconia ceramic. However often only short-term bond strength was used to evaluate the effects of various pretreatment and luting resins on the bond to ceramic [37,44]. There are varieties of storage media, but immersion in 37 °C water is the most common environment because it is easy and reproducible. The most common approach to induce bonding degradation in laboratory research is submerging in water in order to highlight significant differences between the experimental groups [45]. The water degradation aging is a time demanding strategy. In vitro bonding testing after long-term oral simulation is necessary to be performed before clinical recommendation can be provided. To stimulate the oral environment, all of the specimens were stored into the water bath at 37 °C ± 1 for 1day, 30 days and 150 days. Therefore, evaluation of the hydrolytic effect of the materials was one of the aims of the present study. The present result showed that the tensile bond strength varied in accordance with storage periods and the pressures applied.

Further investigations focusing on bond durability after hydrothermal aging and the impact of alumina-sandblasting pressures on flexural strength of translucent partially stabilized zirconia are necessary.

5. Conclusion

In conclusion, combination of 10-MDP containing primers or resin cement and alumina abrasion at 0.2 MPa provided durable and reliable bonding to Y-PSZ zirconia ceramic. When alumina-blasting pressure was lower, higher or not present, no durable bonding to zirconia ceramic was achieved regardless of using 10-MDP containing adhesives. In addition to the selection of an appropriate cement system, optimal bonding to zirconia requires optimization of the sandblasting pressure.

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