Original Article

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The effect of blasting zirconia liner on microtensile bond strength of zirconia to layered and pressed veneers

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Objective: To investigate the effect of sandblasting the zirconia liner on the microtensile bond strength of manually-layered and pressed veneers to zirconia
Materials and methods: Bilayered zirconia specimens were prepared from e.max®ZirCAD framework materials and divided into four groups (at least 30 specimens per group). Two veneering techniques were used: I. Layering technique (e.max®Ceram) for group 1 and group 2 and II. Press-on technique (e.max®ZirPress) for group 3 and group 4. ZirLiner was applied onto the zirconia surfaces in group 1 and 3 and fired according to the manufacturer's instructions. Veneering of these specimens was then performed. The surfaces of group 2 and 4 were treated similarly to group 1 and 3, except that sandblasting with 50-μm aluminum oxide particles was performed on the fired liner material. The bilayered blocks were cut into microbars with 1mm x 1mm in cross-section. All specimens were loaded to fracture using a microtensile tester. The fracture surfaces were analyzed using a scanning electron microscope to identify the mode of failure.
Results: When the liner material was blasted, the mean microtensile bond strength (MTBS) of bilayered specimens in the layering group (14.5±2.7 MPa) and the press-on group (15.5±5.0 MPa) were significantly lower than those of unblasted liner groups (16.5±3.5 MPa for layering and 19.8±6.1 MPa for press-on). Most of the fractures occurring in all groups initiated at the zirconia-veneer interface.
Conclusions: Blasting the zirconia liner material decreased the bond strength between zirconia to layered and pressed veneers. Interfacial failure was predominantly observed in all groups.

Keywords: Layering technique, Microtensile bond strength, Press-on technique, Zirconia liner

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Introduction

In the past decades, all-ceramic materials have been widely used in prosthetic dentistry and the improvement of the ceramic materials with different compositions has been reported [1]. All-ceramic fixed dental prostheses in the posterior teeth can be used with the presence of the zirconia framework fabricated by the CAD/CAM technology [2]. Veneering ceramic is used to cover the zirconia framework for esthetic requirement.

Although the manual layering of the veneer ceramic is the conventional technique for dental technician to create the anatomical form of the restoration, this technique may lead to entrapment of air bubbles, voids, microgaps at the core–veneer interface. These structural defects may cause the stress accumulation and lead to delamination or chipping of the veneering ceramics.

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The press-on technique is another veneering method. The desired tooth structure is fabricated by wax-up onto the zirconia framework and overpressed with the pressable ceramic. The press-on technique using prefabricated ceramic ingots is performed under controlled condition so it might reduce the possibility of thermal fatigue and lead to less incorporation of structural defects in the veneering ceramic [3]. However, the major complication of zirconia-based restorations is delamination or chipping of the veneering ceramics [4].It has been reported that the zirconia frameworks that were veneered using conventional technique showed a chipping rate of 13% within 3 years [5] and 15.2% within 5 years [6]. The fracture rate of porcelain fused to metal restorations was reported only 8%–10% within 10 year [7,8]. Both cohesive fracture of veneering ceramics and interfacial delamination of veneering ceramics from the framework material have been reported whereas the fracture of zirconia framework rarely occurred.[1] To overcome these problems, the bond strength between the zirconia framework and veneering ceramic should be improved for favorable clinical performance and long-term clinical success rate of all-ceramic restorations.

The zirconia frameworks are more acceptable in esthetic appearance than the metal frameworks, however, zirconia is still too white and opaque. Different techniques have been used to adjust the color of zirconia frameworks such as adding coloring oxide to the pre-mixed zirconia powder, immersion the milled frameworks in the coloring solution or application of zirconia liner over the sintered white frameworks [4,9]. Most manufacturers recommend applying the zirconia liner onto the white framework prior to veneering to block out the color of the zirconia. However, the use of zirconia liner onto zirconia framework was still controversial. Some studies reported a decrease in bond strength [10]; while some reported an increase in bond strength [11].

The purpose of this study was to investigate the effect of sandblasting the zirconia liner material on microtensile bond strength of zirconia to layered and pressed veneers and the mode of failure of zirconia to layered and pressed veneers.

Materials and Methods

1. Fabrication of the bilayered zirconia-veneer specimens and microbars

Pre-sintered yttrium-stabilized zirconium oxide blocks (IPS e.max® ZirCAD) were cut using a low speed diamond disc (Isomet 1000). The

Table 1. Four experimental groups in this study categorized according to veneering technique and surface treatment of zirconia liner

Group	Veneering technique	Core material	Liner	Sandblast over fired liner material	Veneer material	Code
1	1. Layering	e.max®ZirCAD	ZirLiner	-	e.max® Ceram	ZLC
2		e.max®ZirCAD	ZirLiner	Sandblast	e.max® Ceram	ZLSC
3	2. Press-on	e.max®ZirCAD	ZirLiner	-	e.max® ZirPress	ZLZp
4		e.max®ZirCAD	ZirLiner	Sandblast	e.max® ZirPress	ZLSZp

cutting surfaces were polished with 1000-grit silicon carbide paper. The blocks (11mm x 11mm x 5.5 mm) were then sintered and cleaned in an ultrasonic bath for 5 minutes and briefly steam-cleaned. Then, they were randomly categorized into four experimental groups (at least 30 samples per group) according to the veneering porcelain fabrication technique and surface treatments (Table 1).

The ZirLiner was mixed and applied on the prepared zirconia blocks and briefly dried and fired according to the firing program (Ivoclar Programat® P100). After firing the liner, its thickness was measured under the measuring microscope. The ZirLiner thickness should be approximately 0.1 mm according to the manufacturer's recommendation.

For ZLSC and ZLSZp groups, the fired liner surface of the zirconia block was gently blasted with aluminum oxide particles (Al_2O_3) 50 µm 1.5 bar at a standoff distance of 15 mm for 5 seconds [12] and then steam-cleaned. For ZLC and ZLZp groups (unblasted liner materials), the fired liner surface was prevented from any contamination before veneering.

The conventional layering technique and press-on veneering technique were used according to the veneering materials; e.max® Ceram: Layering technique and e.max® ZirPress: Press-on technique, respectively (Table 1).

The bilayer block was fixed with cyanoacrylate adhesive gel on a resin acrylic base attached to a micro-cutting instrument (Struers). The first section, 1-mm peripheral rims of the specimens were discarded due to the possibility of the absence of ZirLiner at interfaces that might affect the results (Figure 1A). The block was partially sectioned from veneer to zirconia, leaving 1 mm of intact surface at the end of the block (Figure 1B). The cemented block was then rotated 90° (Figure 1C) and continuously sectioned until microbars of 8 mm in length and 1 mm^2 cross-section were achieved. Only sound microbars with cross sectional area 1.0±0.1 mm^2 were used for testing.

2. Microtensile bond strength test

The sound microbars were randomly selected from each testing group and attached to the attachment unit on the left and right sides with the adhesive (Model Repair II Blue). The bonded bars were loaded to failure within a microtensile tester machine (Bisco) at a 1 mm/min crosshead speed. The maximum load at failure was recorded and the microtensile bond strength value was calculated. The microtensile bond strength (MTBS) values were calculated using the formula, $\sigma = F/A$ where 'F' is the load at failure (N) and 'A' is the cross-sectional area (mm^2) at bonded interface measured using a digital vernier caliper prior to the test.

The mean MTBS and standard deviation of each group were calculated and recorded. Shapiro-Wilk test was performed to test normality

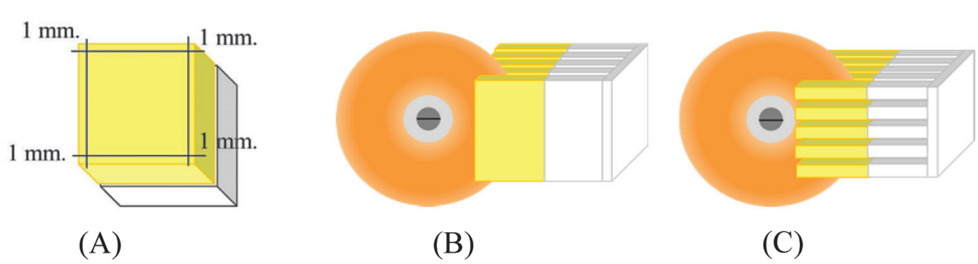


Figure 1. Schematic illustration of microbars preparation. (A) 1-mm peripheral rims of specimens were discarded. (B) The block was partially sectioned, leaving 1.0 mm of intact surface at the end of the block. (C) The cemented block was then rotated 90^0.

of the data and Levene's test was done for equality of variances. Independent t-test was used to compare the mean MTBS between unblasted and blasted zirconia liner materials within the layering and press-on groups at a 5 % significant level.

3. Scanning electron microscope observations of the ceramic surfaces

The surface morphologies of unblasted and blasted fired liner were observed under a scanning electron microscope (JSM-6610LV) at 500X magnification. Fractured specimens were ultrasonically cleaned, dried and then examined under SEM at 80X and 200X magnification. The failures were classified into two modes: (1) Cohesive in porcelain veneer: veneering porcelain still covered the entire interfacial surface after load to failure and (2) Interfacial failure: the fracture originated at the zirconia-veneer interface. Some veneering porcelain remained attached to the zirconia, but some of the interfacial zirconia was visible.

Results

In this study, only the sound microbars with 1.0±0.1 mm^2 cross-sectional area were selected. After discarding the oversized and undersized specimens, the number of specimens used in this study were 30, 34, 35 and 34 for the ZLC, ZLSC, ZLZp and ZLSZp, respectively (Table 2). The mean ZirLiner thickness and the mean cross-sectional areas of the four experiment groups are summarized in Table 2. The mean microtensile bond strength (MPa), standard deviation, and failure mode are listed in Table 3.

The data are normally distributed and the equal variances are assumed in each veneering technique ($p>0.05$). The independent t-test revealed that there was statistically significant difference of the mean MTBS between unblasted and blasted liner material within the layering group ($p<0.05$) and within the press-on group ($p<0.05$) (Table 4).

For the layering group (e.max® Ceram), when the liner material was blasted, the mean MTBS (14.48±2.72 MPa) was significantly lower than that of unblasted liner group (16.48±3.52 MPa) ($p<0.05$). Similarly, for the press-on group (e.max® ZirPress), when the liner material was blasted, the mean MTBS (15.48±4.97 MPa) was significantly lower than that of unblasted liner group (19.83±6.14 MPa) ($p<0.05$).

Modes of failure of specimens in the four experiment groups are shown in Table 3. Interfacial failure is defined as the fracture originated at the zirconia-veneer interface. Some veneering

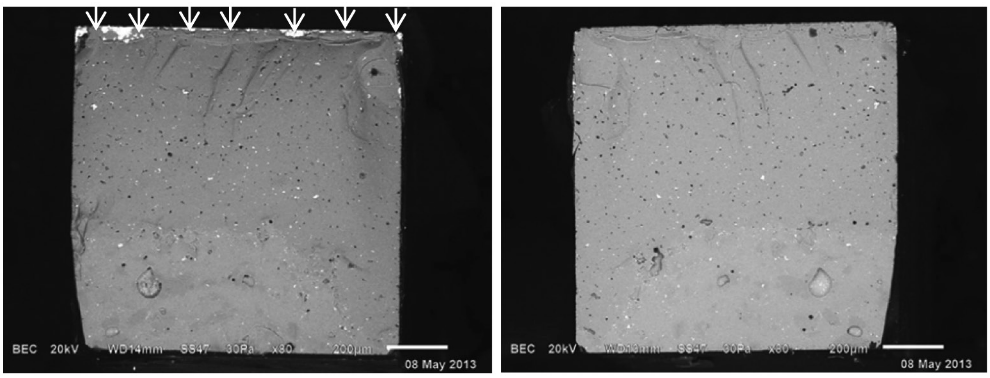
Table 2. Number of specimens (N), mean ZirLiner thickness and mean cross-sectional area

Experiment groups	Code	N	Mean ZirLiner thickness (μm) ± SD	Mean cross-sectional area (mm^2) ± SD
e.max®ZirCAD/ZirLiner/ e.max®Ceram	ZLC	30	145.2±13.1	1.07±0.06
e.max®ZirCAD/ZirLiner/ Sandblast/e.max®Ceram	ZLSC	34	126.3±9.9	1.04±0.04
e.max®ZirCAD/ZirLiner/ e.max®ZirPress	ZLZp	35	149.6±13.8	1.01±0.07
e.max®ZirCAD/ZirLiner/ Sandblast/e.max®ZirPress	ZLSZp	34	117.0±4.8	1.06±0.06

porcelain remained attached to the zirconia, but some of the interfacial zirconia was visible (Figure 2). In cohesive failure, veneering porcelain covered the entire interfacial surface after load to failure (Figure 3). The majority of fractured specimens had interfacial failure (80-100%). Only 3 of 30 specimens in ZLC group and 7 of 35 specimens in ZLZp group fractured cohesively in porcelain veneer.

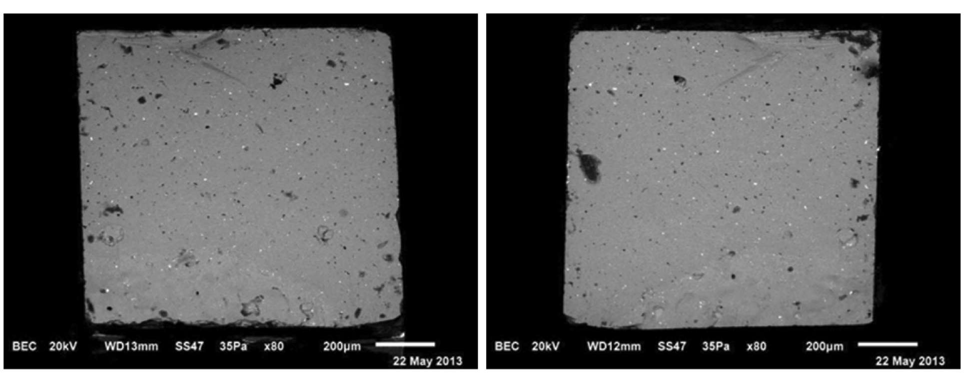
SEM analysis revealed the different surface morphologies of unblasted fired ZirLiner and blasted with 50-µm aluminum oxide particles (Figure 4). On the unblasted fired ZirLiner surface (Figure 4A), porosities due to ZirLiner application process were visible. Sandblasting led to a distinctly rough surface (Figure 4B)

The SEM image of e.max® ZirLiner/e.max® Ceram (Layering technique) (1000X) shows good contact between the liner-veneer interface without microgaps (Figure 5), while the SEM image of e.max® ZirCAD/e.max® ZirPress (Press-on technique) (1000X) shows poor contact between the two materials (Figure 6A). However, sandblasting the fired liner material before pressing the veneer improved the interface between these two materials and eliminated microgaps (Figure 6B).



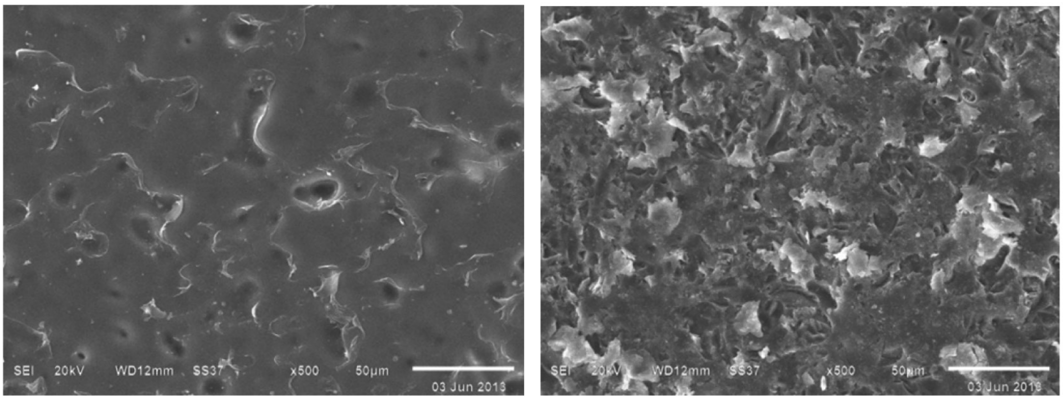
(A) (B)

Figure 2. SEM image (80X) of an interfacial failure of e.max® ZirCAD/ZirLiner/ e.max® Ceram (ZLC). Fracture originated at zirconia-veneer interface, leaving exposed zirconia grains (arrows). (A) Zirconia side and (B) Veneer side



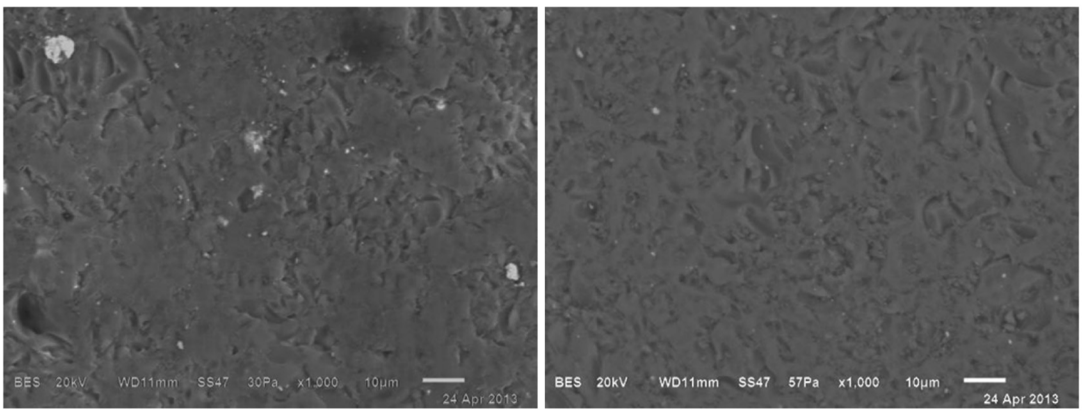
(A) (B)

Figure 3. SEM image (80X) of a cohesive failure in veneering porcelain of e.max® ZirCAD/ZirLiner/e.max® Ceram (ZLC). Fracture originated and propagated in the veneer ceramic. (A) Zirconia side and (B) Veneer side



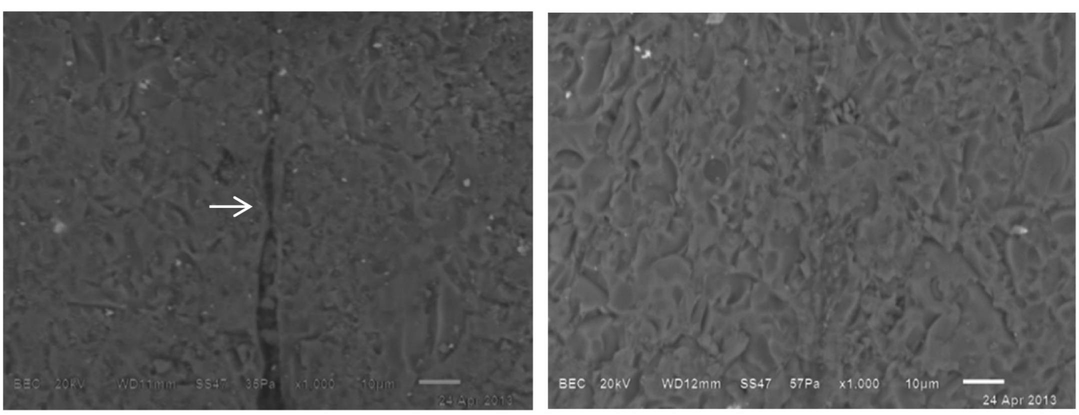
(A) (B)

Figure 4. SEM images (500X) of ZirLiner surfaces: (A) Unblasted ZirLiner surface (B) The fired liner surface after sandblasting with 50-µm aluminum oxide particles



(A) (B)

Figure 5. SEM image of e.max®ZirLiner/e.max®Ceram (1000X) shows good contact between the liner-veneer interface without microgaps. (A) Unblasted liner material and (B) Blasted liner material.



(A) (B)

Figure 6. SEM image of e.max®ZirCAD/e.max®ZirPress(1000X): (A) Unblasted liner material created microgaps between e.max®ZirLiner/e.max® ZirPress. (B) Blasted liner material eliminated microgaps between two materials

Table 3. Number of specimens (N), mean microtensile bond strength (MPa), standard deviation and failure mode of each experiment group

Veneering technique	Group	N	Mean microtensile bond strength (SD)	Mode of failure	
				Cohesive	Interfacial
Layering	ZLC	30	16.48 (3.52)[a]	10%	90%
	ZLSC	34	14.48 (2.72)[b]	0%	100%
Press-on	ZLZp	35	19.83 (6.14)[A]	20%	80%
	ZLSZp	34	15.48 (4.97)[B]	0%	100%

The different superscript letter indicates significant difference by t-test at a 0.05 level of significance

Table 4. Results of the independent t-test for analyzing the difference of the mean MTBS between unblasted and blasted liner material (α = 0.05)

Mean MTBS	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
Within the layering group Equal variances assumed	2.563	62	.013	2.00189
Within the press-on group Equal variances assumed	3.229	67	.002	4.34702

Discussion

The long-term performance of zirconia-based restorations that the success rate over 5 years of service is 85-90% [13-15]. The main cause of failure is chipping or fracture of veneering materials. The fracture of porcelain veneer is either fracture of veneering itself or fracture originated from the zirconia-veneer interface [1]. The reasons for chipping or fracture of veneering materials are the residual stresses generated by the mismatch of coefficients of thermal expansion (CTE) between veneering ceramics and zirconia substructure [16], as well as the insufficient bond strength between these two materials [17]. Zirconia liner which is used to mask the color of the Y-TZP ceramic also influences the bond between Y-TZP and veneering ceramics [11]. Yet, the effect of sandblasting over the fired liner material on microtensile bond strength of zirconia veneered with layered and pressed ceramics was unclear. Therefore, the main purpose of this research is to investigate the effect of sandblasting over the zirconia liner material on microtensile bond strength of zirconia veneered with layered and pressed ceramics.

The microtensile bond strength test has been proven to be a reliable test for determining the core-veneer bond strength [10]. In the present study, the stick-shaped specimen (microbar) of 8 mm in length and 1 mm^2 cross-sectional area was achieved. Due to the small cross-sectional area, it was expected that the stress distribution would be uniform. All specimens were loaded to fracture using a microtensile tester. Most of the fracture occurred in all groups initiated at the zirconia-veneer interface (80-100%). Therefore, this test method could demonstrate the actual zirconia-veneer bond strength between these two materials.

The SEM image (1000X) of the liner-veneer interface of sound microbars (Figure 5) showed that for the manually layering technique, a brushed-on paste procedure showed good wetting of the veneering porcelain (e.max® Ceram) over the unblasted zirconia liner material (e.max® ZirLiner). However, for the press-on technique, the microgaps between the liner-veneer (e.max® ZirLiner/e.max® ZirPress) were observed when the fired liner material was unblasted. These structural defects could interrupt the contact between the unblasted zirconia liner and the pressed ceramics. Aboushelib et al [3] also reported that when the fired liner material was unblasted, the microgaps between liner material and Ceram Express pressable veneer was found. Structural defects were observed when the veneer was pressed over, resulting in poor contact between these two materials and the liner-veneer interface became a potential site for crack initiation. They re commended to sandblast the liner material before pressing the veneer to improve the interface between these two materials. Nevertheless, this method might affect the MTBS value. To enhance the surface contact and increase the surface roughness between the zirconia liner materials and veneering ceramics, blasted fired liner material with 50 μm alumina at 1.5 bars was performed with reference to earlier study [10].

For layering technique, no differences were identified in the liner-veneer interface of both unblasted and blasted liner materials. The microgaps or structural defects between the liner materials (e.max® ZirLiner) and layered ceramics (e.max® Ceram) were not presented in both groups. This might be because the layered ceramics were built-up layer by layer using a brush. This technique demonstrated good wetting of the veneering ceramics even in unblasted liner material. Therefore, sandblasting showed no influence on the liner-veneer interface in the layering technique. However, sandblasting liner material significantly decreased the MTBS between zirconia and layered ceramics.

For the press-on technique, the differences in the liner-veneer interface between unblasted and blasted liner materials were identified. Sandblasting over the fired liner material eliminated microgaps between the liner material (e.max® ZirLiner) and the pressed ceramics (e.max® ZirPress). It might be because sandblasting increased surface roughness, modified the surface energy of liner material and improved wettability of pressable ceramics. However, sandblasting liner material also significantly decreased the MTBS between zirconia and pressed ceramics.

As previously mentioned, the MTBS was significantly lower when the liner materials were blasted in both layering and press-on technique. A possible explanation for this phenomenon is that during sandblasting process, the fired liner material may accumulate the stress and generate the microcracks in the liner material itself. This may lead to decreasing the MTBS of zirconia to layered and pressed ceramics.

Regarding the fracture analysis, the present study found that the failure mode of zirconia veneered with both layered and pressed ceramics was predominantly interfacial failure. Fracture originated at the zirconia-veneer interface that left exposed zirconia surface. Harding et al [12] also found 98% interfacial failure in the MTBS test of Kavo Everest® Y-TZP/e.max® Zirpress. A possible explanation for this study is that sandblasting the fired liner material eliminated microgaps and improved the liner-veneer interface in the press-on technique; however, sandblasting could create the microcracks in the liner material and then the zirconia-liner interface became a potential site for crack initiation and propagation. Therefore, the fracture pattern of blasted liner material in both layered and pressed ceramics to zirconia was 100% interfacial failure without cohesive failure in veneering ceramics. On the other hand, an unblasted fired liner material resulted in poor contact between the liner and veneering materials. Consequently, the liner-veneer interface was susceptible to crack initiation and the fracture pattern was 10-20% cohesive failure in veneering ceramics.

The clinical implication of this study demonstrated that in the zirconia-veneer fabrication process, blasting over the fired liner material before pressing the veneer improved the interface between the two materials. However, it resulted in not only decreasing the MTBS but also increasing the possibility of interfacial failure.

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