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Biaxial flexural strength of ceramic veneering techniques to yttria-tetragonal zirconia polycrystalline

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Abstract

Purpose: This study evaluated the influence of the different veneering technique to zirconia on biaxial flexural strength of ceramic bilayer.

Materials and Methods: Forty-five (45) disc-shape specimens (10 mm in ϕ, 0.5 mm thickness) were prepared from each zirconia (e.max ZirCAD (Z_z), inCoris TZI (Z_i), Cercon (Z_c)) and randomly veneered with either a conventional layering technique, using IPS e.max Ceram (P_c), heat-pressed technique using IPS e.max Zirpress (P_h), and Cad-fused veneering technique using IPS e.max CAD (P_f). The bilayer specimens were adjusted and glazed to the final dimension (10±0.05 mm in ϕ, 1.5±0.01 mm in thickness). Piston on three balls method was used to determine the biaxial flexural strength at 0.5 mm/min cross-head speed. The loads to failure were recorded and calculated for biaxial flexural strengths using Hsueh formula. Data were analyzed through ANOVA, Bonferroni test, and Weibull analysis.

Results: The biaxial flexural strength (Mean±SD; MPa) and Weibull modulus (m) for each group were: Z_zP_c= 623.07±62.07, 11.11; Z_iP_c= 643.97±63.83, 11.30; Z_cP_c= 612.07±70.24, 9.50; Z_zP_h= 660.34±63.6, 11.20; Z_iP_h= 693.13±65.81, 11.69; Z_cP_h= 683.88±61.72, 12.18; Z_zP_f= 935.64±62.37, 16.41; Z_iP_f= 857.34±62.31, 14.98; Z_cP_f=721.34±58.67, 13.79. The flexural strength was significantly affected for different types of zirconia and veneering techniques ($p<0.05$). The CAD-fused veneering technique indicated significantly higher flexural strength than the others ($p<0.05$). Flexural strengths upon using IPS e.max ZirCAD were significantly higher than Cercon ($p<0.05$), but comparable to inCoris TZI ($p>0.05$).

Conclusions: The IPS emax ZirCAD and CAD-fused veneering technique were capable of providing high flexural strength for ceramic veneering zirconia.

Keywords: Flexural strength, Zirconia, Veneering technique

Introduction

At present, certain aesthetics in dentistry plays a significant role on the patient's satisfaction. All ceramic materials become a life saver to overwhelm the limitations of porcelain-fused-to metal restorations, which can provoke allergic reactions in some patients, light transmission inhibition, and produce an unfavorable color on marginal gingiva, as well as aesthetic conflict.(1-5) Among ceramic materials, yttria-tetragonal zirconia polycrystalline (Y-TZP) has recently been introduced as an alternative to metal substructure, due to its great strength and biocompatibility. Y-TZP frameworks, with their polycrystalline nature, exhibit high flexural strength and fracture toughness.(1,5-12) A relatively opaque, proper veneering material is recommended to improve the aesthetic outcomes.(1,5,13-19) However, clinical failures of zirconium dioxide-based fixed partial dental prostheses, such as ceramic veneer chipping, fracture, and the delamination of the ceramic veneer from zirconia core were reported.(1,5,6,8,14,18-24) Maria et al reported that the most common complication of anterior fixed partial dental prosthesis using zirconia was chipping, about 14.8% after seven years.(22) Zarone et al found that the prevalence of ceramic-veneered zirconia failure was in the range of 0-54% after one or two years of service, while the rate of failure for porcelain fused to metal (PFM) was 6% after 10 years.(4) Failure of ceramic veneered to zirconia prostheses is related to multi-factors, such as the coefficient of thermal expansion (CTE) mismatch between the veneering ceramic and zirconia framework materials, residual stress, number of multiple firings, and veneering techniques.(1-3,14-19,24-31) Beside the different veneering techniques, appropriate ceramic veneer and zirconia materials with different ceramic properties may alter the strength of ceramic veneered to zirconia prostheses.(6,11,31-33) Dental ceramic can tolerate compressive stresses better than the tensile stress generated through functional loading, therefore, tensile load may play a key role in the clinical success of dental ceramic restorations.(9,11,19,32)

The aim of this study was to evaluate the effects of different ceramic veneering techniques to three zirconia materials on the flexural strength of ceramic veneer zirconia bilayer. The hypothesis was to determine the significant differences in flexural strength of ceramic veneered to zirconia substructures, due to the different veneering techniques, zirconia materials, and their interaction.

Materials and Methods

The present study included three different veneering techniques (layering, heat-pressed, and CAD-fused) by using three corresponding veneering ceramics, including

IPS e.max® Ceram (P_c; Ivoclar Vivadent, Schaan, Lichtenstein), IPS e.max® Zirpress (P_h; Ivoclar Vivadent, Schaan, Lichtenstein), and IPS e.max® CAD (P_f; Ivoclar Vivadent, Schaan, Lichtenstein). Each type of ceramic was veneered on three different Y-TZP zirconia substructures. These were IPS e.max® ZirCAD (Z_z; Ivoclar Vivadent, Schaan, Lichtenstein), inCoris® TZI (Z_i; Sirona Dental Systems GmbH, Bensheim, Germany), and Cercon® (Z_c; Degudent GmbH, Hanau-Wolfgang, Germany), which using their corresponding veneering techniques.

Zirconia Specimen Preparation: The zirconia specimens were prepared into a disc shape at the dimension of 10±0.05 mm in diameter and 0.5±0.01 mm in thickness. Forty-five (45) disc specimens from each type of zirconia material were prepared from pre-sintered Y-TZP blanks by using a diamond-coated wheel (Isomet® 1000, Beuhler, Illinois, USA) and they were ground down with a silicon carbide abrasive paper at 1200 grit particles. The pre-sintered Y-TZP blank was cut into flat disk shape specimen at approximately 13 mm in diameter and 6.5 mm in thickness, in order to compensate for 20% volumetric shrinkage after the sintering process. All pre-sintered zirconia specimens were sintered in a sinter furnace (inFire® HTC, Sirona Dental Systems GmbH, Bensheim, Germany) according to the manufacturers' recommendations. Each type of sintered zirconia disc specimens was randomly distributed into three groups (15 discs per group), to be veneered with veneering ceramic according to the three veneering techniques: conventional layering, heat-pressed, and CAD-fused technique.

Ceramic Veneering Technique: The zirconia specimens in each group were randomly veneered with three different techniques.

Technique 1: Conventional Ceramic Layering Technique: The zirconia specimens were coated with a thin layer of IPS e.max® Zirliner (Ivoclar Vivadent, Schaan, Leichtenstein), and fired in a porcelain furnace (Programmat® P100 furnace, Ivoclar Vivadent, Schaan, Leichtenstein) according to the instructions of a firing schedule as shown in Table 1. The IPS e.max® Ceram (P_c) powder was then mixed with distilled water into a creamy consistency. That slurry porcelain was brushed on the opaque surface of each specimen, condensed with ultrasonic porcelain condenser (3M Unitex, St. Paul, USA), blotted dry with an absorbent tissue, and then fired according to the manufacturer's recommendation, as shown in Table 1. The body porcelain was added and fired no more than three times to achieve the final dimension of 10±0.05 mm in diameter and 1.5±0.01 mm in thickness. The porcelain was adjusted by wet grinding in sequence to 1500 grit silicon carbide abrasive papers. Then, the specimens were glazed in porcelain furnace, according to the manufacturer's recommendations shown in Table 1.

Technique 2: Heat-pressed Ceramic Veneering Technique: A thin layer of IPS e.max® Zirliner was applied on the zirconia specimen in a similar manner, performed on the layering technique and fired according to the manufacturer's recommendation as shown in Table 1. The blue inlay wax (Kerr, Emeryville, CA, USA) was melted and layered onto the sintered opaque specimen for 1.2 mm thickness. The wax surface was smoothed, sprued, and invested with IPS® Press Vest Speed (Ivoclar Vivadent, Schaan, Leichtenstein) according to the manufacturer's instructions. The investment was left for 45 minutes to fully set and then burnt out in furnace (Magma®, Renfert GmbH, Hilzingen, Germany). The investment mold was then transferred to furnace (IPS EP Press® furnace, Ivoclar Vivadent, Schaan, Leichtenstein) for ceramic pressing technique as per the manufacturer's recommendation schedule shown in table 1. IPS e.max® Zirpress ingot was used for heat-pressed technique into the investment mold at 910ºC by combining 4 bars pressure and operating vacuum. After cooling, the investment was divested by using 50 µm glass beads with 2 bars pressure. A diamond disk was then used to separate the disc specimens from the sprues. A hydrofluoric acid solution of 1% in concentration (IPS e.max® Press Invex Liquid, Ivoclar Vivadent, Schaan, Leichtenstein) was used to clean specimens in an ultrasonic cleaner (Vitasonic II, Vita Zahnfabrik, Bad Sackingeb, Germany) for 5 minutes, in order to remove the reaction layer. Then, the specimens were cleaned under running water for 3 min. Silicon carbide papers at 1500 grit were used to adjust the specimens to their final dimension of 10±0.05 mm in diameter and 1.5±0.01 mm in thickness. All the specimens were glazed in a porcelain furnace as per the manufacturer's recommendation schedule shown in Table 1.

Technique 3: CAD-fused Ceramic Veneering Technique: A CAD-fused technique was performed to achieve veneering ceramic to zirconia by joining ceramic veneering disc to zirconia disc and using a low fusing ceramic material (IPS CAD® crystal/connect, Ivoclar Vivadent AG, Schaan, Leichtenstein). The pre-sintered IPS e.max® CAD block was cut into a flat disc shape specimen by using a diamond-coated wheel and ground flat with 1500 grits silicon carbide abrasive, in order to reach the dimension of 10.5 mm in diameter and 1.1 mm in thickness. The surface of the pre-sintered IPS e.max® CAD disc specimen was coated with a thin layer of IPS e.max® CAD crystal/connect using a brushing technique over the ceramic surface. Then, the sintered zirconia disc was fitted onto the crystal/connect-coated surface of IPS e.max® CAD disc specimen and compressed together by applying slight pressure. The excessive crystal/connect was removed with a brush. Then, the two disc specimen components were fired together in the porcelain furnace (Programmat®P100, Ivoclar Vivadent) according to the firing schedule recommended by the manufacturer as shown in Table 2. The specimens were then adjusted to achieve the final dimension of 10±0.05 mm in diameter and 1.5±0.01 mm in thickness by wet grinding with 1500 grits silicon carbide abrasive. Then, the specimen was glazed according to the firing schedule recommended by the manufacturer as shown in Table 2.

Table 1: Firing parameters for veneering ceramic

Ceramic	Program	T_s (^{0}C)	T_p (min)	R_t (^{0}C/min)	T_f (^{0}C)	T_h (min)	T_{VS} (^{0}C)	T_{VF} (^{0}C)
IPS e.max® Zirline	Opaque firing	403	4.00	60	960	1.00	450	959
IPS e.max® Ceram	Dentin firing	403	4.00	50	750	1.00	450	749
	Glazing	403	6.00	60	725	1.00	450	724
IPS e.max® Zirpress	Dentin firing	700	-	60	910	15	500	910
	Glazing	403	6.00	60	725	1.00	450	724
	Pressing	700	-	60	910	15	500	910

NB: T_s = staring temperature, T_p = preheating time, R_t = rate of increasing temperature per minutes,
T_f = final temperature, T_h = holding time, T_{VS} = vacuum starting temperature, T_{VF} = vacuum shut temperature

Table 2: Firing parameters for crystallization and glazing of IPS e.max® CAD for Cad-fused veneering technique

Program	S (min)	B (^{0}C)	t_1 (^{0}C)	T_1 (^{0}C)	H_1 (min)	t_2 (^{0}C)	T_2 (^{0}C)	H_2 (min)	L (^{0}C/min)	V_1(^{0}C) 1_1 1_2	V_2(^{0}C) 2_1 2_2
Crystallization	6:00	403	60	770	0:10	30	850	10:00	700	550 770	770 850
Glazing	6:00	403	90	820	0:10	30	840	7:00	700	550 820	820 840

NB: S =closing time; B = stand by temperature; t_1, t_2 = heating rate;
T_1, T_2 =firing temperature; H_1, H_2 =holding time; L = long term cooling

Biaxial Flexural Strength Test: All disk-shape specimens were subjected to determination for biaxial flexural strength by using a universal testing machine (Lloyd®, Leicester, England) as shown in Fig. 1. The specimen was concentrically placed on a three-balls supporter (arranged in a supporting ring manner of 5 mm in diameter). A 0.05 mm thick plastic sheet was put between the piston and the surface of the specimen to equally distribute the load. A compressive load was applied on the ceramic veneering side through a piston (1.4 mm in diameter) as shown in figure 2. The load was applied at a crosshead speed of 0.5 mm/minute until specimen fracture occurred. The load at failure was recorded and calculated for the biaxial flexural strength by using Hsueh's formula [34] derived from the equations 1, 2, 3, and 4.

$$\sigma = \frac{-E_1(z-z^*)P}{8\pi(1-v_1)D^*}\left\{1+2\ln\left(\frac{a}{c}\right)+\frac{1-v}{1+v}\left[1-\frac{c^2}{2a^2}\right]\frac{a^2}{R^2}\right\} \ldots\ldots\ldots\text{Equation 1}$$

$$z^* = \frac{E_1t_1^2/2(1-v_1^2)+E_2t_2^2/2(1-v_2^2)+E_2t_1t_2/(1-v_2^2)}{E_1t_1/(1-v_1^2)+E_2t_2/(1-v_2^2)} \ldots\ldots\ldots\text{Equation 2}$$

$$D^* = \frac{E_1t_1^3}{3(1-v_1^2)}+\frac{E_2t_2^3}{3(1-v_2^2)}+\frac{E_2t_1t_2(t_1+t_2)}{(1-v_2^2)}-\frac{\left[E_1t_1^2/(2(1-v_1^2))+E_2t_2^2/(2(1-v_2^2))+E_2t_1t_2/(1-v_2^2)\right]^2}{E_1t_1/(1-v_1^2)+E_2t_2/(1-v_2^2)} \ldots\ldots\ldots\text{Equation 3}$$

$$v = \frac{v_1t_1+v_2t_2}{t_1+t_2} \ldots\ldots\ldots\text{Equation 4}$$

In which: σ = biaxial flexural strength; P = load (newton), E_1= elastic modulus of zirconia core = 210 GPa; E_2= elastic modulus of veneering ceramic (IPS e.max® Ceram = 60 GPa, IPS e.max® Zirpress = 70 GPa, IPS e.max® CAD = 95 GPa); t_1= the thickness of zirconia core; t_2= the thickness of veneering ceramic; v_1= Poisson's ratio of zirconia core = 0.3; v_2= Poisson's ratio of veneering ceramic = 0.25; v= the equivalent Poisson's ratio of the bilayer; a= radius of the supporting ring = 2.5 mm; c= radius of the loading piston ball = 0.7 mm; R= radius of the specimen; z^* and D^* have the physical meanings of the position of neutral plane and flexural rigidity, respectively.

Statistical Analysis of Data: Statistical analysis was performed by using SPSS statistic system for windows (SPSS/PC, version 17.0, SPSS, Chicago, IL, USA). In this study, parametric statistical tests were performed since the data was accepted upon normality test. The flexural strength values of each group were statistically analyzed for their significant effect about the type of zirconia materials and ceramic veneering techniques by using an analysis of variance (ANOVA). The Bonferroni post-hoc multiple comparison was used to determine the significant differences among the tested groups at 95% level of confidence. The biaxial flexural strength values for each group was also analyzed by using Weibull statistics (Weibull^{++} version 6, Reliasoft Corp., Tuczon, AZ, USA) and determined for their probability of failure by using equation 5.

$$P_f = 1 - exp\left[-\left(\frac{\sigma}{\sigma_0}\right)\right]^m \text{ ....Equation 5}$$

Where P_f *is the probability of failure,* σ *is the fracture strength,* σ_0 *is the characteristic strength, and m is the Weibull modulus.*

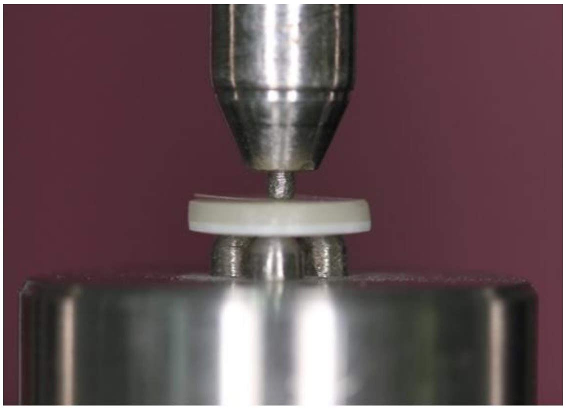

Fig. 1 Biaxial flexural strength testing apparatus with a specimen in place

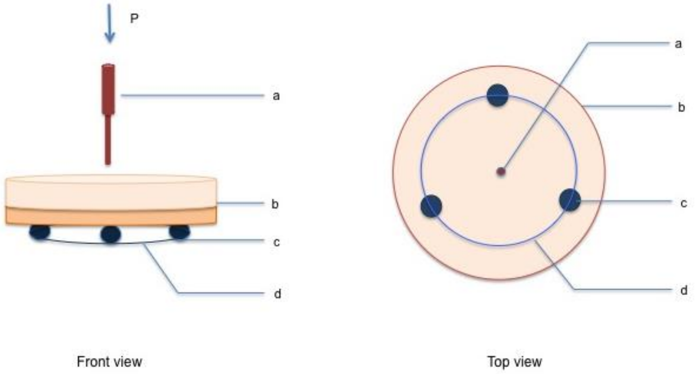

Fig. 2 Schematic showing the piston on three ball of biaxial flexural strength testing

(NB: a =piston loading, b =specimen (ϕ10 mm, 1.5 mm thick), c =steel ball, d =supporting ring (ϕ5 mm), P =load)

Results

The biaxial flexural strength values of ceramic veneering zirconia for each group were reported in terms of the mean and standard deviation and presented in Table 3 and Fig. 3. The mean and standard deviation (X±SD) of biaxial flexural strength was indicated to be the highest in the group Z_zP_f (935.64±62.37 MPa), whereas it was indicated the lowest in the group of Z_cP_c (612.07±70.27 MPa). The values of mean and standard deviation for the other groups were respectively reported as follows: group Z_iP_f (857.34±62.31 MPa), group Z_cP_f (721.34±58.67 MPa), group Z_iP_h (693.13±65.81 MPa), group Z_cP_h (683.88±61.72 MPa), group Z_zP_h (660.34±63.66 MPa), group Z_iP_c (643.97±63.83 MPa), and group Z_zP_c (623.07±62.07 MPa). An analysis of the variance (ANOVA) indicated significant differences of biaxial flexural strength, due to the effects of zirconia materials, ceramic veneering techniques, and the interaction between zirconia materials and ceramic veneering techniques *($p<0.05$)* as shown in Table 4.

A post-hoc Bonferroni multiple comparison test revealed significant difference in the biaxial flexural strength of ceramic veneering zirconia on the different types of zirconia materials ($p<0.05$) as shown in table 5. Zirconia material made from IPS e.max® ZirCAD revealed significant enhancing effect on flexural strength of ceramic-veneered zirconia more than Cercon zirconia ($p<0.05$), but no significant effect compared to inCoris® TZI ($p>0.05$). The capability of providing an effect on flexural strength of ceramic-veneered zirconia revealed no significant difference between IPS e.max® ZirCAD and inCoris® TZI zirconia ($p>0.05$) and between inCoris® TZI zirconia and Cercon® zirconia ($p>0.05$). Therefore, a post-hoc Bonferroni multiple comparison indicated towards significant differences in the biaxial flexural strength of ceramic veneering zirconia on different types of ceramic veneering techniques ($p<0.05$), as shown in Table 5. The CAD-fused veneering technique was capable of providing significant effects on the flexural strength of ceramic-veneered zirconia over both heat-pressed veneering technique and conventional ceramic veneering technique ($p<0.05$). The capability of conventional ceramic veneering technique in providing the effects on flexural strength of ceramic veneered zirconia was significantly lowest when compared to the other techniques ($p<0.05$). A post-hoc Bonferroni multiple comparison indicated the difference in the biaxial flexural strength among the different groups of ceramic veneering zirconia, as shown in Table 6. The group of Z_zP_f indicated towards a significantly high biaxial flexural strength when compared to the other groups ($P<0.05$). The group of Z_iP_f indicated at a significant higher biaxial flexural strength than the other groups ($P<0.05$) except for the group of Z_zP_f. The group of Z_cP_f demonstrated a significantly higher biaxial flexural strength when compared to the groups of Z_iP_c, Z_zP_c, Z_cP_c ($P<0.05$) but it was significantly lower than the groups of Z_zP_f, and Z_iP_f ($P<0.05$) as well, because there were no significant difference to the group of Z_hP_h, Z_iP_h ($p>0.05$). The group of Z_iP_h demonstrated a significantly higher biaxial flexural strength than the groups of Z_cP_c ($P<0.05$). There were no significant differences among the groups of Z_cP_h, Z_zP_h, Z_iP_c, Z_zP_c, and Z_cP_c ($P<0.05$).

The Weibull modulus values ("m") for biaxial flexural strength of each group were reported in Table 3. Weibull values for each group were ranked from the highest to the lowest, which is as follows: Z_zP_f (16.41), Z_iP_f (14.98), Z_cP_f (13.79), Z_cP_h (12.18), Z_iP_h (11.69), Z_iP_c (11.304), Z_zP_h (11.20), Z_zP_c (11.11), Z_cP_c (9.50). The probability values for the failure of the biaxial flexural strength for ceramic veneering zirconia of each group were presented in Fig. 4.

Table 3: Mean, standard deviation, and Weibull modulus (m) of biaxial flexural strength of ceramic veneering techniques on zirconia materials for each tested group

Group	n	Biaxial flexural strength				m
		Mean (MPa)	SD	95% Confidence interval		
				Lower bound	Upper bound	
Z_zP_c	15	623.07	62.07	588.7	657.45	11.11
Z_iP_c	15	643.97	63.83	608.62	679.32	11.30
Z_cP_c	15	612.07	70.24	573.17	650.97	9.50
Z_zP_h	15	660.34	63.6	625.11	695.55	11.20
Z_iP_h	15	693.13	65.81	656.68	729.57	11.69
Z_cP_h	15	683.88	61.72	649.69	718.07	12.18
Z_zP_f	15	935.64	62.37	901.1	970.18	16.41
Z_iP_f	15	857.34	62.31	822.83	891.85	14.98
Z_cP_f	15	721.34	58.67	688.85	753.83	13.79

NB: Z_z = IPS e.max® ZirCAD, Z_i = inCoris® TZI, Z_c = Cercon,
P_c = IPS e.max® Ceram, P_h = IPS e.max® Zirpress, P_f = IPS e.max® CAD

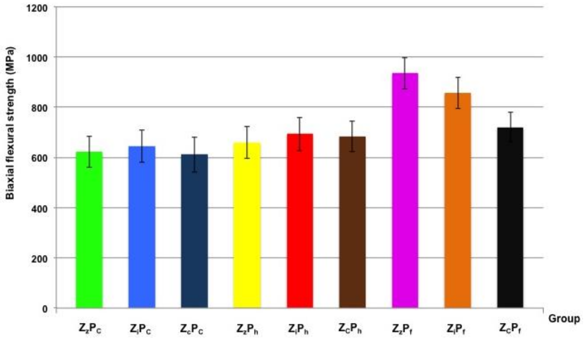

Fig. 3 Biaxial flexural strength of ceramic veneered zirconia among tested groups

(NB: Z_z = IPS e.max® ZirCAD, Z_i = inCoris® TZI, Z_c = Cercon, P_c = IPS e.max® Ceram, P_h = IPS e.max® Zirpress, P_f = IPS e.ma®x CAD)

Table 4: Two-way ANOVA test results for biaxial flexural strength of ceramic veneered zirconia

Source	SS	Df	MS	F	P
Intercept	6.892E7	1	6.892E7	1.711E4	< 0.001
Veneering technique	1093363.090	2	546681.545	135.673	< 0.001
Zirconia material	121152.041	2	60576.020	15.033	< 0.001
Technique*Material	248045.152	4	62011.288	15.390	< 0.001
Total	7.089E7				

NB: SS = sum of squares, Df = degree of freedom, MS = mean square, F = F-test, P = probability value

Table 5: Bonferroni post-hoc multiple comparisons of biaxial flexural strength of ceramic veneered zirconia related to the effect of zirconia matarials and ceramic veneering technique

<table>
<tr><th colspan="4">Bonferroni Post-hoc multiple comparisons of biaxial flexural strength
among three zirconia materials</th></tr>
<tr><td></td><td>IPS e.max® ZirCAD</td><td>inCoris® TZI</td><td>Cercon®</td></tr>
<tr><td>IPS e.max® ZirCAD</td><td>1.000</td><td></td><td></td></tr>
<tr><td>inCoris® TZI</td><td>1.000</td><td>1.000</td><td></td></tr>
<tr><td>Cercon®</td><td>0.000</td><td>0.060</td><td>1.000</td></tr>
<tr><td colspan="4"></td></tr>
<tr><th colspan="4">Bonferroni post-hoc multiple comparisons of biaxial flexural strength
among three ceramic veneering techniques</th></tr>
<tr><td></td><td>Layering technique</td><td>Heat-pressed technique</td><td>CAD-fused technique</td></tr>
<tr><td>Layering technique</td><td>1.000</td><td></td><td></td></tr>
<tr><td>Heat-pressed technique</td><td>0.007</td><td>1.000</td><td></td></tr>
<tr><td>CAD-fused technique</td><td>0.000</td><td>0.000</td><td>1.000</td></tr>
</table>

Table 6: Bonferroni post hoc multiple comparisons of biaxial flexural strength among tested groups

Group	Z_zP_c	Z_iP_c	Z_cP_c	Z_zP_h	Z_iP_h	Z_cP_h	Z_zP_f	Z_iP_f	Z_cP_f
Z_zP_c									
Z_iP_c	1.000								
Z_cP_c	1.000	1.000							
Z_zP_h	1.000	1.000	1.000						
Z_iP_h	.109	1.000	.023*	1.000					
Z_cP_h	.352	1.000	0.86	1.000	1.000				
Z_zP_f	.000*	.000*	.000*	.000*	.000*	.000*			
Z_iP_f	.000*	.000*	.000*	.000*	.000*	.000*	.035*		
Z_cP_f	.002*	.040*	.000*	.344	1.000	1.000	.000*	.000*	

NB: Z_z = IPS e.max® ZirCAD, Z_i = inCoris® TZI, Z_c = Cercon®,
P_c = IPS e.max® Ceram, P_h = IPS e.max® Zirpress, P_f = IPS e.max® CAD

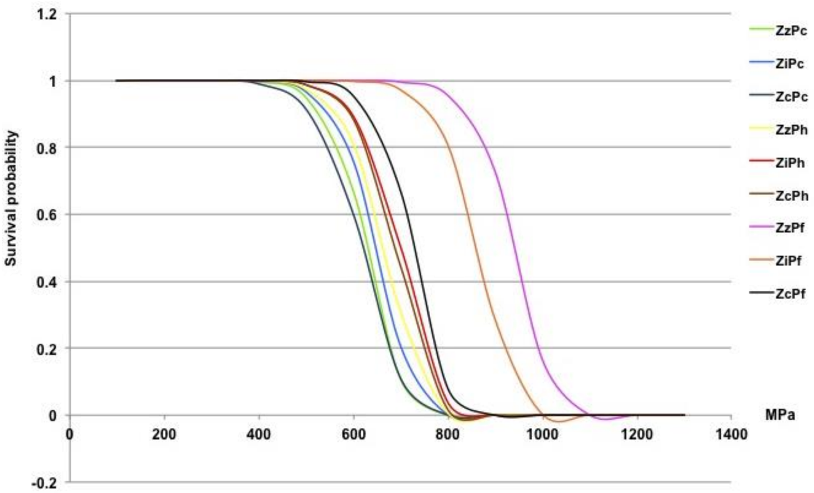

Fig. 4 Relative Weibull analysis curves of biaxial flexural strength among tested groups

(NB:Z_z = IPS e.max® ZirCAD, Z_i = inCoris® TZI, Z_c = Cercon®, P_c = IPS e.max® Ceram, P_h = IPS e.max® Zirpress, P_f = IPS e.max® CAD)

Discussion

The study indicates that the use of different ceramic veneering techniques for different zirconia materials affected the biaxial flexural strength of ceramic veneering zirconia. Thus, the null hypothesis was rejected. The ceramic veneering techniques provided potential effects to the flexural strength of ceramic veneering zirconia due to a fabrication process. A conventional ceramic layering technique was performed through the sintering procedure of the creamy mixture consistency of the ceramic that was condensed over the zirconia and sintered in a porcelain furnace. The flexural strength depended on the quality of ceramic veneering procedure that affects the strength of a ceramic bilayer. Improper ceramic mixing consistency, inadequate condensation, and improper sintering process were reported to increase the porosity in the ceramic.(24,26) The technical skill in the ceramic-veneering procedure and the number of ceramic firing times were reported to contribute for the success rate of the conventional veneering technique.(1,2,31,35) A heat-pressed veneering technique was performed through lost wax technique. A heat-pressed ceramic ingot was heated and pressed onto the zirconia surface. The procedure of the heat-pressed veneering technique was better-controlled when compared to the conventional ceramic layering technique. This procedure was performed under a strictly-controlled environment. The ceramic ingot was heated and pressed to the zirconia in a pressed furnace through pressure in a vacuum environment. The wetting ability and bonding between zirconia and ceramic veneering material were improved. The heat-pressed veneering technique was reported to provide less flaws.(18) Therefore, the flexural strength of ceramic veneering zirconia was indicated to be higher for heat-pressed veneering technique when compared to the conventional ceramic layering technique in this study, and was supported by other studies.(20,28-29) This CAD-fused ceramic veneering technique was based on the bonding of ceramic veneering material to zirconia by fusion glass. Both ceramic veneering material and zirconia were prepared with the aid of the computerized assisting design and computerized assisting manufacturer (CAD-CAM) process. They were joined together through the means of sintering a low-fusing ceramic material. The procedure avoided technically sensitive processes in the dental laboratory when compared to the conventional layering and heat-pressed technique. This technique eliminated the need for multiple firings and was reported to decrease the porosity as well as provide less errors when compared to the others.(24) Thus, the flexural strength was significantly higher than the other veneering techniques, and these were agreed upon with other studies.(15,24)

The strength of the ceramic bilayer was determined through the composition of materials to tolerated the tensile failure.(19,33) Zirconia also demonstrated a significant role in enhancing the strength of the ceramic bilayer. Different zirconia materials possess different properties, and this significantly affects the fracture strength and fracture toughness.(10) The grain size of zirconia was reported to have some influence on the flexural strength, thus, it affected the performance of the material.(7,13,29) Fracture toughness corresponded to propagating crack resistance. Wagner et al concluded that the materials with higher fracture toughness may reinforce the strength.(37) Y-TZP zirconia possessed a high-fracture toughness which was based on transformation toughening property, related to a grain size of less than 1 µm. Different sintering procedure results in different crystal structure and grain size affected the strength of materials.(8) The strength of the ceramic bilayer also depended on the bond strength between zirconia and veneer ceramic.(5,6,14,38) The ceramic veneering zirconia bond strength attributed to the coefficient of thermal expansion (CTE) mismatch between zirconia and ceramic veneering materials, that should be in the acceptable range of 1.0 -1.7 x 10^{-6} K^{-1}.(25,27) Thus, a uniform long cooling procedure for the ceramic veneered zirconia materials was introduced in this study, in order to minimize the residual tensile stress. The Weibull modulus (m) reflected upon the reliability of material. The higher the Weibull modulus of the materials, the better the structural integrity of the materials are predicted.(8,32) Therefore, the range of "m" values from The Weibull modulus of 9.50-16.41 observed in this study was in an acceptable range for most dental ceramic.(10,28,32)

Conclusion

The flexural strength of ceramic-veneered zirconia was influenced through a ceramic-veneering technique, zirconia material, and their interactions. CAD-fused ceramic-veneering technique offered the flexural strength of veneering ceramic to zirconia, which was significantly stronger than conventional ceramic layering technique and heat-pressed veneering technique. The capability of different zirconia material in providing flexural strength of veneering ceramic to zirconia was comparable, except for the IPS e.max® ZirCAD, that was significantly capable to enhancing the flexural strength over Cercon® zirconia, but comparable with inCoris® TZI. Thus all Y-TZP zirconias which were tested in this study, and was recommended to be veneered CAD-fused ceramic veneering technique. However, the IPS e.max® ZirCAD was preferably recommended over the others.

Conflict of Interest: None

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