http://dx.doi.org/10.5392/JKCA.2015.15.09.384

비니어 세라믹과 지르코니아 세라믹의 Push-Shear 결합강도

Push-Shear Bond Strength of Veneering Ceramics and Zirconia Ceramic

안재석*, 노형록, 이정환***
광주보건대학교 치기공과*, 전북대학교 치의과학과**

Jae-Seok Ahn(jsahn@ghc.ac.kr)*, Hyeong-Rok No(dentalmania@hanmail.net)**,
Jung-Hwan Lee(leejh@ghc.ac.kr)*

요약

본 연구에서는 원통형 지르코니아 코어에 다섯 종류의 지르코니아 비니어 세라믹을 축성하여 push-전단 결합강도를 측정하고, 비니어 세라믹의 이축굽힘강도와 지르코니아 글라스 라이너 처리에 따른 전단결합강도 차이를 알아보고자 하였다. 지르코니아 비니어 세라믹은 piston-on-three-ball test로 이축굽힘강도를 측정하였고, 지르코니아 실린더 코어와 비니어 세라믹은 push-shear test로 결합강도를 측정하였으며, 결과값은 이원분산분석을 사용하여 분석하였다. 이축굽힘강도는 Cercon ceram kiss (CE)군에서 가장 높게 측정되었고 전단결합강도는 글라스 처리군과 Triceram(TR)군이 높게 측정 되었으며 Creation ZI(CR)군에서 가장 낮은 값이 측정 되었다. 실험군에서 지르코니아 라이너 처리군이 라이너 처리하지 않는 군보다 전단결합강도가 높게 나타났으며 통계적으로 유의한 차이를 보였다($P<0.05$). 따라서 지르코니아 라이너 처리는 지르코니아와 비니어 세라믹의 결합강도를 향상시킬 수 있는 것으로 사료된다.

■ 중심어 : | 지르코니아 | 지르코니아 비니어 세라믹 | 지르코니아 라이너 | 푸시-전단 결합 강도 | 이축굽힘강도 |

Abstract

The purpose of this study was to evaluate the push-shear bond strength between five commercial zirconia veneering ceramics and zirconia core cylinder, and to investigate the effect of biaxial flexural strength and zirconia liner glass treatments. The biaxial flexural strengths of the veneering ceramics were evaluated by a piston-on-three-ball test. The bond strengths between the Y-TZP cylinder and zirconia veneering ceramics were evaluated using the push-shear bond strength test. The data was analyzed using two-way ANOVA and Scheffe's test. The biaxial flexural strength of Cercon ceram kiss (CE) was higher than those of the other groups. The glass-treated and Triceram zirconia groups showed the highest value and the Creation ZI(CR) showed the lowest. In all groups, the liner glass treatment groups showed significantly higher push-shear bond strength than those without($P<0.05$). The liner glass treatments of zirconia can improve the bond strength between the zirconia ceramic core and veneering ceramics.

■ keyword : | Zirconia | Zirconia Veneering Cerami | Zirconia Liner | Push-shear Bond Strength | Biaxial Flexural Strength |

---

* 본 연구는 광주보건대학교 연구과제로 수행되었습니다.
접수일자 : 2015년 04월 21일
수정일자 : 2015년 06월 02일
심사완료일 : 2015년 06월 12일
교신저자 : 이정환, e-mail : leejh@ghc.ac.kr

Ⅰ. INTRODUCTION

In recent years, continuing improvements of all-ceramic restorations have been made, particularly in the field of the fixed partial dentures (FPDs). In addition to the development of core materials, all-ceramic restorations can provide better esthetics, biocompatibility and mechanical properties compared to porcelain-fused metal (PFM). Since the introduction of all-ceramic systems in the 1980s, a variety of materials can be used as core materials to achieve successful restorations, including glass infiltrated ceramics, lithium disilicate, alumina and zirconia. The most recently introduced core ceramic is zirconium dioxide (ZrO_2) or zirconia. Zirconia core material is so strong that long-span all-ceramic FPDs are possible.

The success of core veneered all-ceramic restorations depends on a complex relationship between the core materials and veneering ceramics. Many variables can affect the core veneered all-ceramic bond strength, such as the surface treatment of the core materials, which can affect the mechanical retention for example Al_2O_3 blasting and grinding, residual stresses generated by mismatches in the coefficient of thermal expansion(CTE), development of flaws and structural defects at the core veneered interface, wetting properties and volumetric shrinkage of the veneering ceramics[1-4]. Recently many studies have reported the complex relationships between core materials and veneering ceramics in core veneered all-ceramic restorations[5-8].

A range of methodologies were designed by researchers seeking accurate measurements of the bond strengths at metal-ceramic systems. These variables should be minimized by standardizing samples and testing method. In general, the 3-point flexural test, which is normally used as a bond strength measurement of metal-ceramic systems and has minimum bond strength of 25MPa, was established. But ceramic samples tested in bending are quite sensitive to edge or surface machining damage. However, an adequate bond strength test for all ceramic materials has not been determined in the reviewed literature[1][9-12].

Various experimental tests have been designed and used to evaluate to adhesion of veneering ceramic to zirconia core. Therefore, several forms of pull or push though shear strength tests have been designed to measure the bond strength of the metal-ceramic system[10][11][13][14].

Shell and Nielsen[13] have used the first pull or push though shear strength test method to evaluate the metal-ceramic bond strength. Various forms of the Shell and Nielsen test have been used by researchers for easily measured bond strength values, consistency and uncomplicated sample preparation.

Modified pull through shear strength test design was introduced by Anthony et al[14]. Their test was accomplished by embedding in dental stone the portion of the rod to which a cylinder of ceramic had been fired. Bond failure occurred precisely at the zirconia core-veneering ceramic interfaces. The push-shear test of this study can confine the failure mode of the sample to the interface and be considered a simple test to evaluate shear bond strengths of zirconia core veneered all-ceramic system. These factors are the basis for the selection in the present study.

Previous studies on the failure rate of core veneered all-ceramic restorations reported that delamination of the veneering ceramic from the core material is a common failure mode[8][15][16]. Recently, some manufacturers recommend a liner glass treatment to improve the bond strength between the zirconia core and veneering ceramics. Aboushelib et al.[17] reported that liner glass treatment was shown to increase the bond strength as an intermediate layer between the zirconia core and veneering ceramic. Assuming that both zirconia core and veneering ceramic bond strength is a clinical requirement to avoid premature failure of zirconia core veneered all-ceramic restorations[18], the mechanical and chemical effects of zirconia surface treatments can affect the core veneered bond strength and the clinical success rate of such restorations[19]. On the other hand, there is a shortage of comparative data on commercially available liner glass materials, and whether or not they are suitable for core veneered all-ceramic restorations.

The aims of this study, which is divided in two parts, were to compare the fracture strength of five commercially available zirconia veneering ceramics by a piston-on-three-ball biaxial flexural test method using circular disc specimens to determine if they can affect the bond strength, and to estimate the effect of surface treatments with and without the application of two types of liner glass treatment, a specially-prepared glass and zirconia liner products, between the zirconia core cylinder and five veneering ceramics using Push-shear bond test[13][14].

II. METERIALS AND METHODS

1. Materials used

Zirconia core cylinder specimens were obtained from experimental industrially manufactured yttria partially-stabilized tetragonal zirconia polycrystalline (Y-TZP sleeve, NSC, Gwangju, Korea) ceramic cylinder (diameter: 3.6 mm; length: 18 mm). The zirconia ceramic cylinders were cleaned, dried and sintered at 1450℃ for 2 h at a heating and cooling rate of 8.3℃/min. After sintering, the zirconia ceramic cylinder specimens (diameter: 2.7 mm; length: 13.5 mm) were sandblasted with 50 ㎛ Al_2O_3(COBRA, Renfert GmbH, Hilzingen, Germany) at 2.5 bars for 15 seconds, treated with a 1 % hydrofluoric acid(HF) solution and cleaned ultrasonically(N=98).

A specially-prepared glass was designed to infiltrate into the zirconia surface to enhance and improve the bond strength between the zirconia cylinder surface and veneering ceramics. Balanced quantities of $11.0La_2O_3$, $16.0Al_2O_3$, $24.0B_2O_3$, $3.0Y_2O_3$, $29.7SiO_2$, $6.0CeO_2$, $2.0TiO_2$, 5.4CaO, 1.1MnO, $1.8Li_2O$ wt%) and color agents were mixed by ball milling for 24 h to achieve an equalized composition. These were sintered at 1450℃ for 2 h at a heating rate of 10℃/min and subjected to fritting with manufacturer 100 mesh (150 ㎛) powder.

2. Preparation of biaxial flexural strength test specimens

Five commercials zirconia veneering ceramics were used [Table 1]: Creation ZI(CR), Cercon ceram kiss(CE), Triceram(TR), IPS e.max(EM) and Zirkonzahn ICE(ZI). Each zirconia veneering ceramic powder was mixed with the corresponding manufacturer's liquid(n=14 per group). Seventy disc specimens (diameter: 17 mm; thickness: 1.5 mm) were prepared using a vibration-condensation method with a stainless steel mold, and sintered in ceramic furnace(P-500, Ivoclar vivadent AG, Liechtenstein) according to the firing schedules recommended by the manufacturer[Table 2]. After self-glazing, all zirconia veneering ceramic specimens were wet ground with SiC paper up to 2000 grit and polished with 1 ㎛ ceramographic cloth and diamond suspensions.

Table 1. Material properties of the veneering materials.

Veneering ceramic (DA3)	Manufacturer	Code	Core matrix	CTE$_{20\text{-}500℃}$ (ppm/℃)
Creation ZI	KLEMA Dental produkte GmbH, Meiningen,Austria	CR	Zirconia	9.5
Cercon ceram kiss	DeguDent GmbH, Hanau-Wolfgang, Germany	CE	Zirconia	9.2
Triceram	Dentaurum GmbH, Ispringen, Germany	TR	Titanium	8.7
E-Max	Ivoclar Vivadent AG, Schaan, Liechtenstein	EM	Zirconia	9.5
Zirkonzahn ICE	Zirkonzahn World Wide, South Tirol,Italy	ZI	Zirconia	9.5

* CTE: coefficient of thermal expansion.
According to the CTE information provided by the manufactures

Table 2. Firing schedules of the veneering materials.

Veneering Materials	Code	Pre-Drying		3TRI (℃/min)	4FT (℃)	5V1	6V2	7HT (min)
		1ST (℃)	2DT (min)					
Creation ZI	CR							
Dentin layer		450	6	45	810	500	810	1
Self glaze		450	6	45	820			1
Cercon ceram kiss	CE							
Dentin layer		450	8	55	830	500	830	1
Self glaze		450	8	55	840			1
Triceram	TR							
Dentin layer		500	8	55	760	500	760	1.5 ~2
Self glaze		450	2	55	760			1
E-Max	EM							
Dentin layer		403	4	50	750	450	749	1
Self glaze		403	4	50	760			1
Zirkonzahn ICE	ZI							
Wash fire		400	2	55	920	500	920	2
Dentin layer		300	6	55	820	500	820	1
Self glaze		300	2	55	820			1

1ST: starting temperature; 2DT: drying time; 3FT: final temperature; 4TRI: temperature rate increase; 5V1: vacuum on; 6V2: vacuum off; 7HT: holding time.

3. Biaxial flexural strength testing and Weibull analysis

Seventy disc specimens were subjected to a piston-on-three-ball(diameter of 3 mm) biaxial flexural strength test. The specimens were first positioned in the sample holder on top of the supporting balls. A crosshead speed of 0.5 mm/min was applied using a universal testing machine(Instron 4201, Instron Co, USA) as designated in ASTM[9]. The Weibull modulus was obtained from the plot of the measured biaxial fracture strength.

$$S = -0.2387\frac{P(X-Y)}{d^2}$$

$$X = (1+v)In(\gamma_2/\gamma_3)^2 + \left[\frac{1-v}{2}\right](\gamma_2/\gamma_3)^2$$

$$Y = (1+v)[1+In(\gamma_1/\gamma_3)^2] + (1-v)(\gamma_1/\gamma_3)^2$$

where S=the maximum center tensile stress(MPa) and the flexural strength at fracture; P=total load causing fracture(Newtons); v=Poisson's ratio(n=0.25); r_1=radius of supporting circle(mm); r_2=radius of loaded area(mm); r_3=radius of specimens (mm); d=specimen thickness at fracture origin (mm).

Table 3. Weibull analysis data of zirconia veneer ceramic specimens.

Group Parameter	CR	CE	TR	EM	ZI
σ f(0.5)	127.0	133.2	119.6	116.9	113.7
m	5.97	5.27	9.39	7.16	6.39
σ 0	136.7	140.8	126.8	126.4	117.3
r2	0.96	0.97	0.93	0.98	0.99
SD	23.1	26.2	14.0	18.1	18.3
N	14	14	14	14	14

*σ f (0.5)=median fracture strength in MPa; m=Weibull moudulus; σ 0= characteristic strength in MPa; r2=Weibull distribution regression coefficient squared; σ f (avg)= mean fracture strength in MPa; SD=standard deviation; N=number of samples.
CR = Creation ZI; CE = Cercon ceram kiss; TR = Triceram; EM = E-Max; ZI = Zirkonzahn ICE

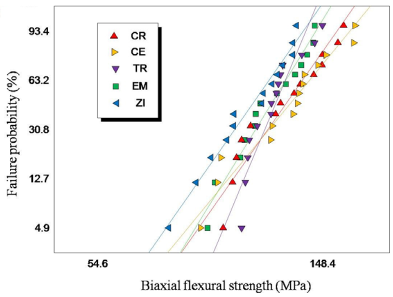


Fig. 1. Weibull plots of flexural strengths of zirconia veneering ceramics specimens.

4. Preparation of push-shear bond strength test specimens

A specially-prepared glass infiltration was conducted at the temperature of 1000 °C for 50 min. Excess glass was removed by sandblasting with 50 ㎛ Al_2O_3 at a maximum pressure of 2.5 bars. After ensuring that excess infiltration glass had been removed, the zirconia core cylinder specimens were heat treated at 960 °C X 1 min and sandblasted with 50 ㎛ Al_2O_3 at a pressure of 2.0 bars for a period of 20 s and then treated with a 0.5 % Hydrofluoric acid(HF) solution for 10 min and cleaned ultrasonically(n=35).

Each zirconia liner powder was mixed on a glass slab using the mixing liquid and the slurry obtained applied to the zirconia core cylinder specimens(n=28). All firing steps followed the exact procedure recommended by the manufacturer's procedure[Table 4].

Table 4. Firing schedules of the liner materials.

Veneering Materials	Pre-Drying		TRI (℃/min)	FT (℃)	V1 (℃)	V2 (℃)	HT (min)
	ST (℃)	DT (min)					
Creation ZI Liner	450	2	55	900	500	900	1
Cercon ceram kiss Liner	575	8	55	970	600	970	1
Triceram Liner	500	4	65	800	500	800	1
E-Max Liner	403	4	60	960	500	959	1
Glass	500	5	55	1000	550	1000	50

All prepared zirconia core cylinder specimens were placed in an adjustable mold on a base made from the modified pull through shear strength test design 10). The refractory die investment materials (Lamina Vest II, SHOFU INC, Kyoto, Japan) mixed with investment liquid under vacuum for 30 s. The creamy refractory die investment material was poured into the mold and dried at room temperature for 60 min before placement for 45 min in a burnout furnace (Miditherm 100, BEGO USA Inc, Lincoln, RI, USA) preheated to 700 °C for 15 min and then moved into a calibrated ceramic furnace (Programat P300, Ivoclar, Liechtenstein) preheated at 700 °C and then the temperature raise with a heat rate of 50 °C/min until the temperature reached 1050 °C, with a hold time of 1 minutes. After preheating, all refractor die cylinders (diameter: 6 mm; height: 10 mm) were positioned on top of mold. The mold was carefully filled with the creamy mixture of each zirconia ceramic and condensed to final dimensions (diameter: 6 mm; width: 2 mm). Excess liquid was removed by applying a piece of adsorbing paper (Kimwipes Lite 200, Kimberly Clark, Koblenz, Germany) onto the surface. After condensation, the mold was removed, leaving the non-sintered refractory die cylinders, which were transferred to a firing tray and sintered in a ceramic furnace in accordance with each manufacturer's instructions[Table 2]. Remnants of refractory investment material were removed by sand blasting with 50 ㎛ Al_2O_3 at 2 bar of atmospheric pressure. The Push-shear bond strength testing specimens were mounted using a precision parallelometer(Seasin surveyor-Ⅱ, Youjin dental, Korea) with type Ⅲ dental stone(Snow rock, Mungyo, Korea)[Fig. 2].

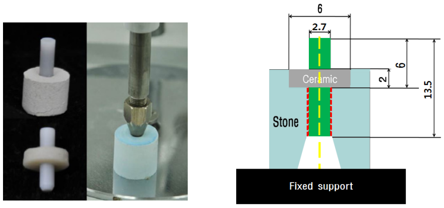


Fig. 2. Photograph and Schematic illustration of specimen used in this study.

5. Push-shear bond strength testing and statistical analysis

The push-shear bond strength was measured using a universal testing machine(Instron 4201, Instron Co, USA) at a crosshead speed of 0.5 mm/min. The fractured surfaces were observed by scanning electron microscopy(JEOL, JSM-5800, Japan) and optical microscopyLeica, EZ4D, Germany). These analyses were used to examine the mechanisms of failure as well as the nature of the interface between the treated surface and veneering porcelain.

The push-shear bond strength means from each group from were analyzed by two-way ANOVA for the effect of surface treatment and liner glass. A post hoc Scheffe's test was used(p=0.05) (SPSS 17.0; SPSS Inc, Chicago, USA).

Ⅲ. RESULTS

[Table 4] lists Weibull analysis of the biaxial flexural strength for the five commercial zirconia veneering ceramic materials. The mean flexural strength ranged from 109.39 MPa to 129.8 MPa. Group Zirkonzahn ICE (ZI) had the lowest strength (109.39 MPa, SD=18.35) and Creation ZI (CR) had the highest strength (129.8 MPa, SD=26.22). Group CR, CE, TR, EM and ZI were similar ($p>0.05$). The Weibull moduli were 5.97, 5.27, 9.39, 7.16 and 6.39 respectively.

After blasting with 50 ㎛ Al_2O_3, a SEM evaluation of the experimental zirconia core cylinder surfaces showed that the zirconia grains were expelled, creating a keying effect that provides a good retention of veneering ceramics[Fig. 3]. The failure mode observed for the Creation ZI liner(CRL) was combined mainly as adhesive failure at the interface and cohesive failure in the veneering ceramic. Adhesive failure mode with delamination of the veneering ceramic from an intact zirconia core structure were observed with Creation ZI(CR) and IPS e.max(EM) groups without a specially-prepared glass and zirconia liner products[Fig. 4]. Mixed failure rates were observed in the remaining groups with both cohesive and combined failure.

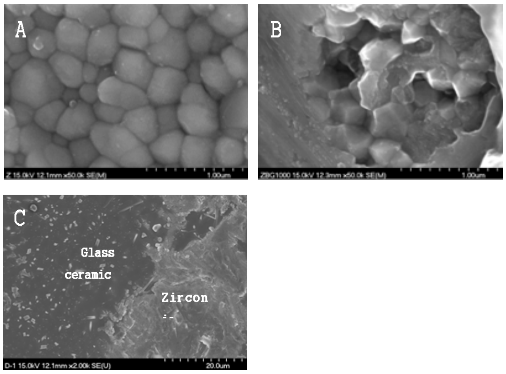


Fig. 3. (A) SEM image of Y-TZP ceramic sintered at 1,450℃ for 2h, (B) after sandblasting with 50 ㎛ Al2O3, (C) Y-TZP ceramic surface after glass infiltration(5% HF 90seconds).

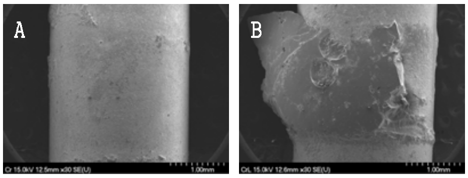


Fig. 4. (A) Low magnification SEM micrograph showing a representative sample of adhesive failure; (B) low magnification SEM micrograph of combined failure.

[Table 5] shows the results of the push-shear bond strength. Creation ZI(CR) had the lowest shear bond strength(20.12 MPa, SD=6.34) and Triceram(TR) had the highest strength(66.62 MPa, SD=10.01). There was a significant difference in the shear bond strength, with the exception of Cercon ceram kiss (CE) ($p<0.05$).

Table 5. Statistical results in push-shear bond strength. Numbers of specific failure types are represented in percentages.

Group	Mean (S.D.) MPa		Adhesive (%)	Cohesive (%)	Mixed (%)
	Initial crack	Final fracture			
CR	15.07 (3.63)a	20.12 (6.34)a	100	0	0
CRL	50.32 (13.36)b	58.51 (9.98)b	0	0	100
CRG	37.28 (6.52)c	37.28 (6.52)c	29	0	71
CE	26.40 (9.74)	28.17 (11.22)	71	0	29
CEL	26.80 (5.93)	38.58 (5.00)	29	0	71
CEG	26.05 (4.65)	33.91 (4.08)	43	0	57
TR	45.91 (18.62)	66.62 (10.01)a	0	0	100
TRL	35.87 (5.82)	43.41 (7.15)b	29	0	71
TRG	54.18 (15.40)	64.25 (7.89)b	14	0	86
EM	30.90 (7.83)a	33.10 (7.03)a	100	0	00
EML	38.32 (2.68)a	43.45 (5.83)a	29	0	71
EMG	29.98 (3.08)b	31.10 (2.79)b	71	0	29
ZI	33.81 (11.78)	38.17 (8.53)	86	0	14
ZIG	36.45 (11.74)	48.68 (4.10)	43	0	57

Ⅳ. DISCUSSION

In order to evaluate the bond strength of core veneered all-ceramic systems, 3-point flexural test, micro-shear and micro-tensile tests have been used. Unfortunately, each test has their limitations as specimen fabrication and the mechanical integrity of the veneering ceramic. An adequate bond strength test for all ceramic materials has not been determined. However, one of the most common tests to evaluate bond strength is the shear bond test. In this study, the push-shear bond strength test method was selected because of easily measured shear bond strength values, consistency, and simple specimen fabrication[10][11][13][14].

At first, this study examined the extent to which the biaxial flexural strengths of five commercially available zirconia veneering ceramics affect the bond strength between the zirconia core cylinder and commercially available veneering ceramics. The Weibull analysis used in the present study showed that the m values ranged from 5.96 to 9.38 as the Weibull modules are similar in most specimens. These results are consistent with those of previous studies[20-24]. Five commercially available zirconia veneering ceramics showed biaxial flexural strength values in the range of 109.39-129.8 MPa, which did not differ significantly($p>0.05$). The results indicate that biaxial flexural strength of five commercially available zirconia veneering ceramics wouldn't affect the bond strength between the zirconia core cylinder and veneering ceramics.

On the other hand, in the fracture failure pattern of biaxial flexural strength test, 91 % of the specimens 4-7 were fracture pieces. According to the ASTM C 1449[25] guidelines, the fracture origin were evaluated as high and medium energy-high strength failure. The number of failure pieces was greater under increased high flexural strengths.

The bonding mechanisms of veneering ceramics to zirconia surfaces are still unclear. To improve bond strength, wetting ability of veneering ceramics and the use of a liner glass treatment is assumed based on investigations on surface treatment with sand blasting[15][26-28].

SEM of the experimental zirconia core cylinder surfaces showed that the zirconia grains were expelled[Fig. 3B]. Surface roughening of the zirconia core cylinder by blasting with 50 ㎛ Al_2O_3 may have an advantage in bond strength improvement. When the zirconia core cylinders undergo glass liner treatment, they are melted at high temperatures to form ceramic composite and to get wet zirconia surface. The silica layer left by the liner glass treatments are bonded to each other by strong covalent bonds with a zirconia veneering ceramic[Fig. 3C].

The failure mode of an all-ceramic system with a relatively weak bond strength tends more to adhesive chipping of the ceramic at lower fracture loads, whereas a higher bond strength provokes to a certain extent mixed and cohesive failure mode at higher loads. This type of failure mode indicates a good interfacial bond between the zirconia core and veneering ceramic material[29][30].

In the push-shear bond strength test, three catastrophic failure modes were observed: adhesive, cohesive and mixed failure mode. The most promising results showed that the zirconia liner groups had higher mean push-shear bond strength. The failure mode observed for Triceram(TR) and with the zirconia liner groups were mainly mixed mode; adhesive at the interface and cohesive in the veneering ceramic[Fig. 4B]. The described failure mode with the adhesive of the veneering ceramic from the intact zirconia surface was comparable to the results of other reports[17][31].

For the bond strength value of the veneering ceramic on a zirconia all-ceramic core, it was reported that the different bond strength with a 3.4-61.0 MPa range can be evaluated by the mismatch thermal expansion coefficient(CTE), different surface treatment, etc[26][32]. Derand et al[27] reported that a 20 - 40 MPa shear bond strength can be assumed. The mean push-shear bond strength values of the liner and glass infiltration group are approximately 20 % higher than the groups without liner glass treatment, except for the Triceram liner(TRL) group. Significant differences in the push-shear bond strength were observed in the zirconia core veneered all-ceramic system with and without the liner and glass infiltration(Table 5). In addition, to apply glass infiltration to the Zirkonzahn ICE Glass group(ZIG), the push-shear bond strength was approximately 27 % higher than that without. Interestingly, Triceram(TR) and Triceram glass infiltration(TRG) showed approximately 50 % higher mean push-shear bond strength than the Triceram liner(TRL). That may be because CTE mismatch($0.6x10^{-6}K^{-1}$) could be expected from the Triceram liner-veneer system[Table 1].

Almost all manufacturers of veneering ceramic for zirconia ceramic provide liner glass materials to assist in wetting and to adjust the chemistry, chroma, CTE and increased interaction. Based on the push-shear bond strength results of the present study, bond strength between zirconia core and the veneering ceramics requires the application of liner glass treatment to overcome the existing thermal incompatibilities between the zirconia core and veneering ceramics, and to match the values[33].

As the limitations of this study the authors admit that the push-shear bond strength test specimens investigated do not represent clinical shape and oral conditions, but provide a geometry that permits shear bond strength measurement. Therefore, further studies, in the development of a zirconia core and veneering ceramic interface will be necessary for clinical long term success.

V. CONCLUSION

The present study employed the push-shear test design to evaluate shear bond strength of IPS e.max(EM), Creation ZI(CR), Cercon ceram kiss(CE), Triceram(TR) and Zirkonzahn ICE(ZI) zirconia veneering ceramics both with and without liner glass materials.

There wasn't significant difference in the mean biaxial flexural strength of five commercial zirconia veneering ceramics and the fracture patterns considering medium energy - medium strength failures and high energy - high strength failures observed. The result of biaxial flexural strength tests indicated that it in fact wouldn't affect the bond strength between the zirconia core cylinder and veneering ceramics.

Based on the push-shear bond strength results of the present study, a comparison of all groups revealed the liner glass treatment groups to have significantly higher push-shear bond strengths than those without and the application of liner glass materials reduce delamination of the veneering ceramics. These results suggest that liner glass treatment should be performed on zirconia all-ceramic system to improve the bond strength. Further study will be needed to overcome the existing thermal incompatibilities between the zirconia core and veneering ceramics.

참고문헌

[1] G. Isgrò, P. Pallav, J. M. van der Zel, and A. J. Feilze, "The influence of the veneering porcelain and different surface treatments on the biaxial flexural strength of a heat-pressed ceramic," J Prosthet Dent, Vol.90, No.5, pp.465-73, 2003.

[2] M. Guazzato, T. R Walton, W. Franklin, G. Davis, C. Bohl, and I. Klineberg, "Influence of thickness and cooling rate on development of spontaneous cracks in porcelain/zirconia structures," Australian Dental Journal, Vol.55, No.3, pp.306-310, 2010.

[3] M. V. Swain, "Unstable cracking (chipping) of veneering porcelain on all-ceramic dental crowns and fixed partial dentures," Acta Biomaterials, Vol.55, No.5, pp.1668-1677, 2009.

[4] M. Tholey, N. Thiel, S. Schindler, S. Rues, and J. Lenz, "Temperaturgradienten in Kronen mit Gerusten aus Zirkoniumdioxid (Y-TZP). Quintessenz der Zahntechnik," Vol.36, No.9, pp.1184-1198, 2010.

[5] A. Sundh and G. Sjögren, "Fracture resistance of all-ceramic zirconia bridges with differing phase stabilizers and quality of sintering," Dent Mater, Vol.22, No.8, pp.778-784, 2006.

[6] R. P. Christensen and B. J. Ploeger, "A clinical comparison of zirconia, metal and alumina fixed-prosthesis frameworks veneered with layered or pressed ceramic: a three-year report," Journal of the American Dental Association, Vol.141, No.11, pp.1317-1329, 2010.

[7] P. C. Guess, A Kulis, S. Witkowski, M. Wolkewitz, Y. Zhang, and J. R. Strub, "Shear bond strengths between different zirconia cores and veneering ceramics and their susceptibility to thermocycling," Dental Materials, Vol.24, No.11, pp.1556-1567, 2008.

[8] N. Z. Fahmy, "Bond strength, microhardness, and core/veneer interface quality of an all-ceramic system," Journal of Prosthodontics, Vol.19, No.2, pp.95-102, 2010.

[9] ASTM Standard F394-78, *STM Annual Book of Standards,* Vol. 15.02, Section 16. American Society for Testing and Materials, Philadelphia, PA, pp.466-490, 1996.

[10] C. W. Fairhust, P. E. Lockwood, R. D. Ringle, and W. O. Thompson, "The effect of glaze on porcelain strength," Dent Mater, Vol.8, No.3, pp.203-207, 1992.

[11] J. S. Shell and J. P. Neilsen, "Study of the bond

between gold alloys and porcelain," J Dent Res, Vol.41, pp.1424-1437, 1962.

[12] M. Dundar, M. Ozcan, B. Gokce, E. Comlekoglu, F. Leite, and L. F. Valandro, "Comparison of two bond strength testing methodologies for bilayered all-ceramics," Dent Mater, Vol.23, No.5, pp.630-636, 2007.

[13] J. S. Shell and J. P. Neilsen, "Study of bond strength of dental porcelain fired to metal," Dent Res, Vol.23, No.5, pp.32-36, 1996.

[14] D. H. Anthony, A. P. Burnett, and D. L. Smith, "Brooks MS. Shear test for measuring bonding in cast gold alloy-porcelain composites," J Dent Res, Vol.49, No.15, pp.27-33, 1970.

[15] H. M. Al-Dohan, P. Yaman, J. B. Dennison, M. E. Razzoog, and B. R. Lang, "Shear strength of core-veneer interface in bi-layered ceramics," J Prosthet Dent, Vol.91, No.4, pp.349-355, 2004.

[16] J. R. Kelly, J. A. Tesk, and J. A. Sorensen, "Failure of all-ceramic fixed partial dentures in vitro and in vivo: analysis and modeling," J Dent Res, Vol.74, No.6, pp.1253-1258, 1995.

[17] M. N. Aboushelib, C. J. Kleverlaan, and A. J. Feilzer, "Microtensile bond strength of different components of core veneered all-ceramic restorations. Part II: Zirconia veneering ceramics," Dent Mater, Vol.22, No.9, pp.857-863, 2006.

[18] M. N. Aboushelib, A. J. Feilzer, and C. J. Kleverlaan, "Bridging the gap between clinical failure and laboratory fracture strength tests using a fractographic approach," Dental Materials, Vol.25, No.3, pp.383-391, 2009.

[19] S. M. Weger and M. Kern, "Long-term resin bond strength to zirconia ceramic," J Adhes Dent, Vol.2, No.2, pp.139-147, 2000.

[20] M. Cheng, W. Chen, and K. R. Sridhar, "Biaxial flexural strength distribution of thin ceramic substrates with surface defects," International Journal of Solid and Structure. Vol.40, No.9, pp.2249-2266, 2003.

[21] S. Ban and K. J. Anusavice, "Inflence of test method on failure stress of brittle dental materials," J Dent Res, Vol.69, No.12, pp.1791-1799, 1990.

[22] J. B. Wachtman, W. Capps, and J. Mandel, "Bi-axial flexure tests of ceramic substrates," J Mater, Vol.7, No.2, pp.188-194, 1972.

[23] J. F. McCabe, and A. W. Walls, "The treatment of results for tensile bond strength testing," J Dent Res, Vol.14, No.4, pp.165-168, 1986.

[24] K. J. Anusavice, C. Shen, B. Vermost, and B. Chow, "Strengthening of porcelain by ion exchange subsequent to thermal tempering," Dent Mater, Vol.8, No.3, pp.149-152, 1992.

[25] ASTM C 1499-03. *Standard test method monotonic equibiaxial flexural strength of advanced ceramics at ambient temperature obsolete, America:* American society for testing materials, 1999.

[26] J. P. Moffa, A. A. Lugassy, A. D. Guckes, and L. Gettleman, "An evaluation of nonprecious alloys for use with porcelain veneers. Part I. Physical properties," The Journal of Prosthetic Dentistry, Vol.30, No.1, pp.424-431, 1973.

[27] M. N. Aboushelib, N. de Jager, C. J. Kleverlaan, and A. J. Feilzer, "Microtensile bond strength of different components of core veneered all-ceramic restorations," Dent mater, Vol.21, No.10, pp.984-991, 2005.

[28] T. Derand, M. Molin, and K. Kvam, "Bond strength of composite luting cement to zirconia ceramic surfaces," Dent Mater, Vol.21, No.12, pp.1158-1162, 2005.

[29] I. Denry and J. R. Kelly, "State of the art of zirconia for dental applications," Dental materials, Vol.24, No.3, pp.299-307, 2008.

[30] E. Tsalouchou, M. J. Cattell, J. C. Knowles, P. Pittayachawan, and A. McDonald, "Fatigue and fracture properties of yttria partially stabilized zirconia crown systems," Dent Mater, Vol.24,

No.3, pp.308-318, 2008.

[31] H. M. Ashkanani, A. J. Raigrodski, B. D. Flinn, H. Heindl, and L. A. Mancl, "Flexural and shear strengths of ZrO_2 and a high-noble alloy bonded to their corresponding porcelains," J Prosthet Dent, Vol.100, No.4, pp.274-284, 2008.

[32] B. Kim, Y. Zhang, M. Pines, and V. P. Thompson, "Fracture of porcelain-veneered structures in fatigue," J Dent Res, Vol.86, No.2, pp.142-146, 2007.

[33] P. Benetti, F. Pelogia, L. F. Valandro, M. A. Bottino, and A. D. Bona, "The effect of porcelain thickness and surface liner application on the fracture behavior of a ceramic system," Dental Materials, Vol.27, No.9, pp.948-953, 2011.

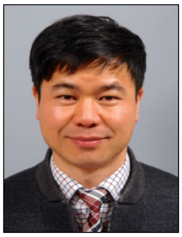
저자소개

안 재 석(Jae-Seok Ahn) 정회원

- 2006년 2월 : 고려대학교 보건학과(보건학석사)
- 2015년 2월 : 전북대학교 바이오나노시스템공학과(공학박사)
- 2010년 3월 ~ 현재 : 광주보건대학교 치기공과 교수

<관심분야> : 치과재료, 생체재료

노 형 록(Hyeong-Rok No) 정회원



- 2007년 2월 : 광주보건대학교 보건학과(보건학사)
- 2013년 2월 : 전북대학교 바이오나노시스템공학과(공학석사)
- 2013년 3월 : 전북대학교 치의학과(박사과정)
- 2014년 3월 ~ 현재 : 광주보건대학교 치기공과 외래교수

<관심분야> : 치과재료, 세라믹

이 정 환(Jung-Hwan Lee) 정회원

- 2006년 2월 : 서울과학기술대학교 정밀화학과(이학석사)
- 2010년 2월 : 전북대학교 바이오나노시스템공학과(공학박사)
- 2006년 3월 ~ 현재 : 광주보건대학교 치기공과 교수

<관심분야> : 치과재료, 생체재료, 고정성 보철학