

Original Article

## Comparative Study of Shear Bond Strength of Three Veneering Ceramics to a Zirconia Core

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### Abstract

**Statement of Problem:** Fracture of veneering porcelain has been described as the most frequent reason for the failure of zirconia-based fixed restorations.

**Objectives:** The purpose of this study was to evaluate and compare the shear bond strength of a zirconium oxide core material to three commercial veneering ceramics.

**Materials and Methods:** Three types of veneering ceramics were selected including IPS -emax Ceram, Vita VM9, and Cerabien. Thirty block specimens of zirconia core material were prepared in 4×4×9 mm dimensions. Three groups were created and the veneering ceramic was added to each of 10 blocks. Shear bond test was conducted with universal testing machine. Data were analyzed using one-way ANOVA ( $p = 0.05$ ).

**Results:** Mean shear bond strength values and standard deviations were 26.03 MPa (6.32), 23.85 MPa (4.01), and 19.16 MPa (3.72) for Vita VM9, IPS emax Ceram, and Cerabien, respectively. Cerabien ceramic showed more failure as compared to the other ceramics. However, there was no significant difference among the three veneering groups.

**Conclusions:** Within the limitation of this study, it can be concluded that shear bond strength between zirconia core and three veneering ceramics was not significantly different.

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## Introduction

All-ceramic restorations have been dramatically improved during the recent decades. The reason for increasing the demand for such restorations is basically aesthetics and biological complications reported about traditional metal-ceramic restorations [1,2]. Among various all-ceramic materials introduced in the recent years, zirconium-oxide (zirconia; ZrO<sub>2</sub>) ceramic materials are one of the proper options for fixed restorations [3].

According to short and medium-term clinical studies, these materials are an appropriate option for frameworks in terms of stability and strength [4-7]. However, the main disadvantage of zirconia restorations is the chip off fracture of porcelain veneer which has been reported to be higher than that of metal-ceramic ones [8]. Therefore, bonding between veneer and core, and also the mechanical properties of the veneering ceramics play important roles in the success of these restorations [9].

Two types of fractures have been reported for zirconia restorations: cohesive and adhesive fractures. Cohesive failures indicate fractures within core or veneer, while adhesive failure refers to delamination of veneer off the core [10,11]. Factors affecting adhesion and cohesion mechanisms in zirconia restorations are coefficient of thermal expansion (CTE) compatibility between veneer and core, framework surface finish and pretreatments, wettability of veneer on the core, micromechanical retention, and firing process [10,12,13].

Different surface treatments have been suggested to improve veneer-core bonding in the zirconia restorations. Polishing, grinding, sandblasting, silica

coating of zirconia surface and the use of laser are among the methods used to increase this bonding through chemical and/or mechanical retention [14-16]. Delamination of veneer off the core occurs as a result of residual stress developed during firing and cooling processes due to coefficient of thermal expansion (CTE) differences between veneer and core, and also incomplete heating of veneer on the core because of low thermal conductivity of zirconia [13,17-23].

The strength of the veneering ceramics, and also their bonding strength to the zirconia core are crucial factors for preventing the fracture of these restorations. There are different veneering ceramics in the market which are claimed they can safely be used with zirconia cores. However, there is not enough scientific data supporting their suitability for this purpose in terms of their bond strength to the zirconia cores. The aim of this study was to evaluate shear bond strength (SBS) of three brands of ceramics as veneering porcelains on zirconia cores. The null hypothesis was that there is no significant difference in the SBS of these veneering ceramics to the zirconia cores.

## Materials and Methods

Thirty zirconia-based blocks (Zirkonzahn, Steger, Ahrntal, Italy) with dimension of 4x4x12 mm were prepared using universal milling machine (Steger, Ahrntal, Italy) (Figure 1. A). The blocks were divided into three groups and placed in the sintering oven (Zirkonzahn, Italy) at room temperature which was raised to 1500 °C during 4 hours, and then remained in that temperature for 2 hours. Thereafter, the samples



**Figure 1:** **A.** zirconia-based blocks (Zirkonzahn, Steger, Ahrntal, Italy) prepared at 4x4x12 mm dimensions. **B.** Three brands of veneering ceramics used for layering the zirconia cores.

were bench cooled to the room temperature during 10 hours. All the sintering procedure was followed according to the manufacturer’s recommendation.

The bonding surface of the core blocks were finished using silicon carbide papers, grit 800 and then 1200 (Matador, Germany) in combination with water spray. Then, they were treated by 50 µm air-borne particles of aluminum oxide with 2 bar pressure, for 10 seconds with 10 mm distance to the blocks. Subsequently, the blocks were cleaned in the ultrasonic bath, with 10 ml of 70% methanol alcohol for 5 minutes, and then they were dried using an oil free air compressor (Nardi compressor model extreme; Italy) at the end [22].

One of three veneering ceramics was used in each group: IPS emax Ceram (Ivoclar-Vivadent, Schaan, Liechtenstien), Vita VM9 (Vita, Bad Sackingen, Germany), and Cerabien ZR (Noritake, Nagoya, Japan) (Table 1), (Figure 1.B). Each veneering ceramic was baked on ten zirconia cores (4x4x3 mm) at the manufacturer’s recommended temperature. A thin layer of shade base (liner) was applied on the cores at first and preheated at 600 °C for 6 minutes

an appropriate amount of the respective liquid were mixed to form the sticky slurry, which was filled into the mould [22].

The same firing procedure was performed for firing the veneer ceramics according to the manufacturer’s instruction, except for the firing temperature that was 930 °C. The samples were then mounted in the universal testing machine (Zwick Roell AG, Ulm, Germany) for measuring the shear bond strength between the veneers and the cores. The shear force at the crosshead speed of 1mm/min was applied vertically to the bonding interface until the fracture occurred. The resultant force (N) was divided by the bonding area (mm<sup>2</sup>) [Shear Stress (Mpa) = Load (N)/Area (mm<sup>2</sup>)]. One-way ANOVA was used to compare the mean shear bond strength between the groups. ZPV-test XPERT software V11.02 was used for statistical analysis. The level of significance was set to be 0.05.

**Results**

The mean and standard deviation (SD) of shear

**Table 1:** Presentation of the three veneering ceramics used in the study

Ceramics	Type	Liner lot No.	Liquid lot No.	Dentin lot No.	Manufacturer
Cerabien ZR	Feldespathic	OE720	OEY01	201611	Noritake, Nagoya, Japan
IPS e.max Ceram	Lithium disilicate	H30927	H33669	H24320	Ivoclar, Schaan
VM9	Feldsphatic	15420	7728	30580	Vita, BadSackingen, Germany

according to the manufacturer. Then, the oven temperature was raised to 950 °C for 4 minutes in the vacuum condition and maintained in this temperature for 1 minute with no vacuum. Thereafter, the oven door was opened when the temperature was decreased to 600 °C. The samples were bench cooled to the room temperature before applying the veneer ceramics. To standardize the porcelain veneer thickness, a plastic split mould cavity was used. Ceramic powder and

bond strength of each group is presented in Table 2. According to the results, Vita VM9 showed the highest bond strength to the zirconia cores (26.03 MPa). The lowest value of shear bond strength was observed in the group with Cerabien ceramic (19.16 MPa). The shear bond strength of IPS emax Ceram group was (23.85 MPa). However, there was no statistically significant difference between the three groups in terms of shear bond strength (*p* > 0.188).

**Table 2:** The mean values, standard deviation (SD), minimum and maximum of shear bond strength of the study groups

Core/Veneer	Mean SBS (MPa)	SD	Minimum (MPa)	Maximum (MPa)
Zirkonzah/Vita VM9	26.03	6.32	16.68	64.43
Zirkonzahn/IPS e.max Ivoclar	23.85	4.01	16.55	34.69
Zirkonzahn/Cerabien ZR Noritake	19.16	3.72	13.46	25.55

### Discussion

The null hypothesis was supported since there was no statically significant difference between the shear bond strength of three tested veneering ceramics to the zirconia cores. The shear bond strength (SBS) test was used in the current study to measure the bond strength of three different veneering ceramics to the zirconia cores of one single brand (Zirkonzahn). Zirconium-based restorations are one of the popular aesthetic restorations that provide both esthetic and function as fixed restorations. However, one of the concerns about these restorations is the bond strength between the veneer and core which might result in debonding during function [13,17,18].

Despite the existence of a standard test of bond strength (three point bending test) and a minimum of 25 MPa bonding strength for veneering ceramic to the metal substructure in metal-ceramic restorations [24], there is no standardized test and a minimum vital bond strength for all-ceramic restorations yet [25]. There are different tests for evaluating the bond strength of veneer to the underlying ceramic core in all-ceramic restorations, including shear bond test [25], microtensile test [22], three and four point bending [26], and biaxial flexure strength tests [12]. The selected test in the current study was shear bond strength which is a simple and reliable test. However, this method may produce more non-uniform stresses at the interface in comparison to microtensile bond test [20]. Nevertheless, cracks at the adhesive zone may be induced during specimen preparation by the cutting and preparing the samples.

The reported core-veneer bond strength in all-ceramic samples reported by previous studies ranged from 9.4 MPa to 42 MPa. [10,17,22,25]. The mean

SBS values in the present study (19.16, 23.85, 26.03) also comply with the range reported by other studies. However, none of the aforementioned studies have investigated the exact ceramic brands as veneering and core ceramics.

There are several factors that might have an effect on the bond strength of the veneer to the zirconia core, including cooling rate, polishing, sandblasting/silica coating of the zirconia surface, properties of veneer and core material, use of a liner material, use of colouring green stage zirconia, firing time duration, cooling rate, and thermo cycling, and thermal compatibility between core and veneer (CTE) [15-23]. Plastic and elastic deformations of the metallic frameworks could approximately compensate for the excessive stresses arising from coefficient of thermal expansion mismatch in metal-ceramic systems [27].

However, the zirconia framework has a higher rigidity and, therefore, can cause more destructive stresses in zirconia-based restorations [28]. Therefore, using veneering ceramics with the least coefficient of thermal expansion difference is crucial for success of all-ceramic restorations. In this study, we used veneering ceramics with acceptable thermal expansion coefficient ranges in relation to zirconia core ( $9.1-10.2 \times 10^{-6}/K$ ). According to Fischer *et al.* [19], the mean CTE of zirconia is  $10.8/K$ , while the mean CTE of IPS emax Ceram, VM9, and Cerabien ZR are 10.4, 9.3, and  $9.9/K$ , respectively.

The resultant mean SBS values of three different veneering ceramics to the zirconia cores were not significantly different which supported the null hypothesis. The small difference of CTE between the core and the veneering ceramics had minimal effect on the bond strength of the samples. This might explain the acceptable SBS of all the veneering

ceramics to the zirconia core. Also, following manufacturer instruction in surface preparation and firing procedure ensures achieving the results claimed by the veneering ceramic manufacturer regarding the compatibility with a zirconia core. Furthermore, according to Aktas *et al.* [20], the veneering ceramic properties affected the results of shear bond strength to the zirconia core, although neither the zirconia core material nor colouring had significant effects on the results. However, they used different veneer and core materials in their study, except for IPS e.max Ceram as one of the veneering ceramics.

Also, Fazi *et al.* [21] showed that tensile strength of VitaVM9 veneer ceramic to the zirconia core was more than other veneering ceramics including Creation ZI and Lava ceram, although there was no significant difference between the three groups. This is in agreement with the findings of this study. However, Ozkurt *et al.* [17] observed that the SBS of VitaVM9 veneer ceramic to the Zirkozahn cores was significantly greater than other groups in their study. However, Aboushelib *et al.* [22] revealed high SBS between a press-on ceramic and a Cercon zirconia core (37.9 MPa). Although the veneering and core materials in their study was different, this finding might indicate that the press-on technique could result in a more strong bond between veneer and core ceramics as compared to the layering technique.

Nevertheless, the results of most of the studies that performed macro shear bond test showed that most fractures occurred in the veneering layer (cohesive failure) [25-28]. This finding implies that the feldspathic ceramics used with layering technique might not provide sufficient strength for veneering of zirconia cores in the final result. Therefore, comparing feldspathic and press-on ceramics in terms of their acceptability for usage with zirconia cores also need to be addressed in terms of the prevalence of cohesive and adhesive failures. It has also been shown that cyclic loading can be a cause of premature cracking and failure [15-23]. Feldspathic porcelain veneer is more sensitive to both static contacts and cyclic loading [29].

In order to perform a valid comparison between the studies, one should consider all the possible factors and conditions that might have an effect on the results. Some interfering factors such as storage conditions, type of specimen used, the preparation method, rate of load application, cross-sectional

surface area, and the operator experience are effective in the findings of the studies [17]. The limitations of the present study suggest that future studies should be performed under dynamic loadings, in a humid environment, simultaneous testing of the effect of modifying the core surface, and also considering the effect of core geometry on the final results. Also, other brands of zirconia cores and veneering ceramics need to be studied using other testing modalities before use in the clinical situations.

## Conclusions

Within the limitation of the present study, there was no significant difference between three veneering ceramics (IPS emax Ceram, Vita VM9, and Cerabien ZR) to the zirconia cores (Zirkozahn) in terms of shear bond strength.

**Conflicts of interest:** None declared.

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