

Original Article

## Shear Bond Strength of Porcelain to a Base-Metal Compared to Zirconia Core

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### Abstract

**Statement of Problem:** Recent clinical results for Zirconia all-ceramic restorations have revealed that the fracture rate 6-15% of the Zirconia framework is so low and the core of Zirconia has high stability. However, chipping-off fractures of porcelain are the most common reason for failures of Zirconia in the fixed partial dentures.

**Objectives:** The purpose of this study was to compare the shear bond strength (SBS) of porcelain in the porcelain fused to metal and all-ceramic crowns with Zirconia core.

**Materials and Methods:** Two groups were selected: porcelain fused to metal (PFM) and porcelain fused to Zirconia (PFZ) (n = 30). In the PFM group, a wax model (10 × 10 × 10mm) was used to cast metal base (Ni-Cr alloy). In the PFZ group, an acrylic cubic model (10 × 10 × 10mm) was made as Zirconia model for scanning. 15 cubic Zirconia samples were milled by CAD-CAM. The procedure of porcelain veneering was conducted by the conventional layering technique up to 2 mm thickness (2.5 × 2.5 × 2 mm). All specimens were stored in water for 48 hrs. Thermal cycling was conducted for 20000 cycles between 55°C and 5°C alternatively for 30s. All samples were mounted in acrylic resin and the SBS test was performed, using a universal testing machine. The analysis of data was performed at a significance level of 0.05 using Kolmogorov-Smirnov and Mann-Whitney U-test.

**Results:** Mean of SBS in PFM and PFZ was 24.57 and 20.88, respectively. The results of Mann-Whitney test showed that there was no statistically significant difference between the two groups of porcelain fused to metal and Zirconia in item shear bond strength ( $p = 0.455$ ).

**Conclusions:** There was no significant difference between the two groups of PFM and PFZ in the item SBS.

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## Introduction

In prosthodontics, the porcelain fused to metal (PFM) crowns has been considered a gold standard system in fixed partial dentures (FPDs) for 40 years [1]. This reliable choice can not only provide aesthetic characteristics similar to the natural teeth, but also enjoys mechanical features such as high flexural and shear bond strength (SBS). In recent years, the increasing requisition for aesthetic restorations as well as discussible toxic role of some dental alloys makes the development of another non-metal restoration justifiable [2].

Different studies revealed an excellent success rate for porcelain fused to zirconia (PFZ) crowns in comparison with PFM crowns [3,4]. Yttria-stabilized Zirconia polycrystal (Y-TZP) has been used in recent years as a core material for all-ceramic restorations. It has high mechanical strength compared to other materials such as alumina and feldspathic porcelains (flexural strength of 900-1200 MPa, and fracture toughness of 9-10 MPa) [5]. Most of the mechanical strength is the result of transformation of monoclinic to a tetragonal structure due to its features of Y-TZP. It could tolerate occlusal loading. The conventional techniques (cupping) such as slip-casting and CAD-CAM ones are used for the frameworks of fixed-dental prostheses (FPDs) [6,7].

Recent clinical results for Zirconia all-ceramic restorations revealed that the fracture rate of the Zirconia framework is so low and Zirconia core has high stability [8,9]. However, chipping-off fractures of porcelain are the most common reason for failure of Zirconia in FPDs [8,9]. The rate of porcelain fracture in Zirconia in FPDs is extremely high in comparison with that in PFM [8]. It seems that the weakness in layered Zirconia-based porcelain is caused by the gap of bonding between the veneer material and the core of Zirconia. For longevity of restorations, this weakness has to be critically considered [9-10]. Long-term studies indicate that the fracture rates of porcelain in PFMs are 2.7-5.5% for a follow-up period of 10 to 15 years [11,12].

Clinical studies have revealed a high rate of fracture for porcelain-veneered zirconia-based restorations varying between 6% and 15% over a 3- to 5-year period. These are high values compared to the 4% fracture rate shown by conventional metal-ceramic restorations over 10 years [13].

The mechanism of adhesion between metal and porcelain is the micro-mechanical bond, van der

Waals force, the coefficient of thermal expansion (CTE) match, and the interaction of ions between the metal and porcelain [14,15]. Studies revealed that the bond strength of ceramic to metal layers was strong enough for functional load (54 - 71 MPa) [16-19].

Furthermore, the mechanism of bonding of zirconia to porcelain is still unknown, but based on few studies, the wettability of the ceramic and Zirconia surface, chemical bonding, and micromechanical interactions play a key role in this regard [17]. However, limited data exist on the bond strength of full ceramic crowns with Zirconia core [4,10].

The aim of this study was to compare the shear bond strength (SBS) of porcelain to a base metal compared to Zirconia.

## Materials and Methods

### *Preparation of the Metal Core Specimens*

At first, 15 wax cube-shaped specimens were prepared ( $10 \times 10 \times 10$  mm). Six layers of wax were superimposed to make a 10-mm thickness. Then, the cubes ( $10 \times 10 \times 10$  mm) were casted in Nickel-chromium base metal alloy (4all, Ivoclar, Liechtenstein, Germany); they were sand-blasted and steam-cleaned (according to the standard ISO 6872). All specimens were fabricated by one dental technician.

### *Preparation of the Zirconia Core Specimens*

A cubic shape silicone mould was filled with acrylic resin and then scanned. Fifteen cubic Zirconia samples (IPS e.max zirCAD) were milled by CAD-CAM (Amangirbach, Germany) with  $10 \times 10 \times 10$  mm. They were sintered at 1,500 °C, dried, and sand-blasted with Al<sub>2</sub>O<sub>3</sub> (120 μ). The measurements were verified by the Digital Caliper Vernier (Mitutoyo, Japan, 0.01 mm). The cores were soaked in ultrasonic cleaner (Digital Ultrasonic Cleaner cd4820, Taiwan) for 10 minutes.

### *Porcelain Application for the Metal Group*

At first, base metal copings were sand-blasted for each porcelain; then, degassing process was performed at 600 to 1000 °C for 18 min. (Auto therm 100, Koushafan Pars Co., Iran). They were sand-blasted by aluminum oxide (120 μ). The procedure of veneering was performed by the conventional layering technique according to manufacturers' instruction. First, two layers of opaque porcelain (E.Maxceram, Ivoclar, Liechtenstein) with 0.5 mm thickness were applied and fired; then, the dentin porcelain was compressed

**Table 1:** Descriptive results of comparison of shear bond strength of PFM & PFZ

Type/Item	Mean	95% CI		Median	IQR
		Lower	Upper		
PFM*	24.57	19.45	29.69	19.40	8.00
PFZ#	20.88	17.81	23.95	20.80	8.00

\*Porcelain Fused to Metal

#Porcelain Fused to Zirconia

with 1.5 mm thickness by the vibration blotting technique and fired for glaze based on the manufacturer's instructions up to 2 mm thickness. Finally, the specimens were stored in water for 48 hrs.

#### Porcelain Preparation for the Zirconia Group

Zirconia core (e.maxceram, Ivoclar, Liechtenstein) was sintered at 1530°C for 12 hrs. (Programat, Ivoclar, Liechtenstein). Then, according to the manufacturer's instructions porcelain (E.Maxceram, Ivoclar, Liechtenstein) was applied up to 2 mm thickness and fired at 750°C for 19 min and glazed for 18 min.

All specimens were stored in water for 48 hrs. Thermal cycling (Thermocycler plus, Willytec, Grafelfing, Germany) was conducted for 20000 cycles between 55°C and 5°C alternatively for 30s to simulate the oral function for a two-year period for all samples of two groups.

#### Shear Bond Strength Test (SBS test)

All samples were mounted in acrylic resin. The SBS test was conducted using a piston in a universal testing machine (Zwick/Roll Z020; Zwick GmbH & Co, Germany) based on the ISO 6872 standards. The SBS test was conducted by placing the Zirconia/metal core at the side with a crosshead speed at 1 mm/min until failure. The maximum force at the time of

fracture was recorded; the SBS test was calculated using the formula below:

$$\text{Shear Stress (Mpa)} = \frac{\text{Load(N)}}{\text{Area(mm}^2\text{)}}$$

#### Statistical Analysis

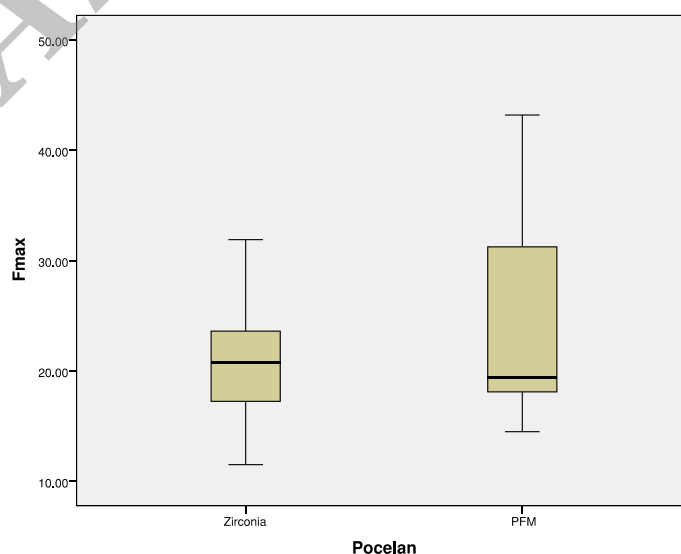
The analysis of data was performed at a significance level of 0.05 using the statistical software SPSS16.0 (SPSS, Inc., Chicago, IL). Kolmogorov-Smirnov test was used to assess the assumption of normality. Data were described using the median and interquartile range (IQR). Mann-Whitney U-test was used to compare the SBS between the two groups.

#### Results

Table 1 shows the descriptive statistics of the SBS measurements. The distribution of the SBS values in the groups was significantly deviated from normality ( $p = 0.015$ ). Mann-Whitney U-test revealed that there were no significant differences between shear bond strength of porcelain to base metal alloy and Zirconia groups ( $p = 0.455$ )(Figure 1).

#### Discussion

The aim of this study was to compare the SBS to base

**Figure 1:** Results of the study in maximum force Shear Bond Strength for PFM & PFZ

metal (Nickel- chromium alloy) and Zirconia core. Nowadays, the usage of Zirconia core is controversial due to lack of evidence in comparison with gold standard choice (i.e. PFM) [20,21]. Many factors were discussed for the application of Zirconia core. One of the main factors to discuss is the SBS [20,22].

Based on the results, there were no significant differences between PFM and PFZ in the SBS. ( $p = 0.455$ ). On the contrary, Turk *et al.* [23] stated that the SBS of the zirconia was significantly less than that of metal in pressing technique. However, the effect of different veneering techniques on the fracture strength of metal and zirconia frameworks was not significant.

In addition, the results of the studies by Aboushelib *et al.* [24] and Ansong *et al.* [25] were similar to those obtained by Subash *et al.* [26]. Nonetheless, Ishibe *et al.* [27] reported in their study that the mean shear bond strength for pressed Zirconia ceramic specimen ranged from 21.34 (24.30) MPa to 40.41 (10.28) MPa, ( $p < 0.05$ ), while it ranged from 30.03 (9.49) MPa to 47.18 (12.99) MPa, ( $p < 0.05$ ) for the layered Zirconia specimens, indicating the presence of higher bond strength value for layered samples than pressed specimens. Farzin said that conventional layering on base metal alloy had lower bond strength than heat press [28].

To meet ISO 9693 requirement, the mean debonding strength/crack initiation strength should be greater than 25 MPa. Owing to inherent brittleness of all-ceramic core materials, this test cannot be applied to the all-ceramic multi-layered system. There are still more choices among all bond strength test methods for these kinds of systems like three-four-point loading test, biaxial flexure test, and micro-tensile bond strength [19].

We decided to use the SBS test method due to its simplicity (the ease of specimen preparation and simple test protocol) and the ability to rank different products according to bond strength values, but the SBS test has some disadvantages such as high standard deviations, occurrence of non-uniform interfacial stresses, and the influence from specimen geometry. Therefore, the standardization of specimen preparation, cross-sectional surface area, and rate of loading application are important to improve the clinical usefulness of the SBS test.

Oh *et al.* showed that in the metal groups, both the core thickness and the fabrication method of the veneering porcelain significantly affected the fracture strength, while only the fabrication method affected

the fracture strength in the zirconia groups [29].

Another factor influencing the bond strength is surface treatment. Different surface treatments of Zirconia, such as airborne-particle abrasion, application of a liner and creation of graded glass-Zirconia structures, sandblasting with  $Al_2O_3$ , grinding are proved to significantly improve the Zirconia-porcelain bond strength [21,22,30,31] But In our study no surface treatment was done.

On the other hand, Özkurt *et al.* revealed that the bond strength between Zirconia core and veneer was affected by the types of Zirconia and veneering materials used. Therefore, it is recommended that each type of Zirconia bonding should be used with manufacturer-recommended veneering ceramics [30].

All the five powders, Duceram Kiss, Vita VM13, Ceramco 3, Noritake EX-3, and Vintage, have bond strengths higher than the required 25 MPa minimum for Cr-Co alloy [28]. Moreover, due to its inherent properties such as high biocompatibility, chemical stability, aesthetics, and outstanding flexural strength, Zirconia may be the best substitute for PFM restorations. Nevertheless, Zirconia needs some improvements in these features to reach this goal [22,30].

Furthermore, as a limitation of our study, we suggest that further studies should be designed to evaluate and compare other comparable factors of each material such as color, and flexural strength. According to the available evidence, it is recommended that each material should be compared with different porcelain applying techniques.

## Conclusions

Due to the limitations of our study, as to the SBS, zirconia can be used for crown core. It is recommended that other mechanical and aesthetic factors should be evaluated. Moreover, different porcelain powders should be compared.

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**Conflict of Interest:** None declared

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