Influence of Different Zirconia Thickness on the Shear Bond Strength to Porcelain Veneer

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Abstract

Background The high strength and fracture toughness of zirconia have supported its extensive application in dentistry. For esthetic reasons, zirconia has been veneered with porcelain. However, the fracture of veneering porcelain remains one of the primary causes of failure. **Objectives** The present study aimed to evaluate the effect of different zirconia thicknesses on the shear bond strength of porcelain veneers. **Materials and Methods** Twenty-one zirconia discs of 10 mm in diameter divided into 3 groups according to the thickness of 1, 2, and 3 mm. According to manufacturer instruction of porcelain buildup, the discs veneered to cylindrical porcelain of 5×3 mm of diameter and height respectively. Shear bond strength test (SBS) was conducted with a crosshead speed of 1 mm/min. Data analyzed by One-way ANOVA, and LSD post hoc test at ($p \leq 0.05$). **Results** In this study, different thicknesses of zirconia discs show a significantly affected on the shear bond strength to porcelain veneer. **Conclusion** The increase in the thickness of the zirconia substructure provides a highly significant increase in the mean value of shear bond strength between zirconia and porcelain veneer.

Keywords: Porcelain veneer; shear bond strength; temperature gradient; zirconia thickness

Introduction

The application of zirconium dioxide as a substructure material for all ceramic-veneered restoration has become a relevant replacement to conventional used metal-ceramic restoration due to its superior esthetic, mechanical, and chemical properties. Zirconia-based restorations of fixed dental prostheses and crowns provide benefits when compared with metal-based restoration (Göstemeyer et al, 2010). Unfortunately, the porcelain veneer of zirconia restoration is susceptible to more chipping due to the weakness of the zir-conia-ceramic interface when compared to the metal-ceramic interface. The chipping of porcelain veneer on the zirconia core has been stated to be 4 times than metal-ceramic over five years (Alhasanyah et al, 2013). Experimental studies have proposed the possible causes of high porcelain chipping rate such as the relationship between substructure thickness and the coefficient of thermal expansion; mismatch coefficient of thermal expansion between the zirconia coping and veneer ceramic; and poor adhesion between ceramic and zirconia coping (Tang et al, 2017). Ther-

mal properties among (Y-TZP) and porcelain include the coefficient of thermal expansion (CTE), thermal conductivity and diffusivity, and thermal tempering stresses (Meira et al, 2013). It was demonstrated that CTE of porcelain must be lower the substructure, as the difference between them is negative, the delamination of veneer may occur. Y-TZP balance from sintering temperature to room temperature is slow because it conducts heat lower than veneer porcelain. It results in temperature gradient during cooling (Lungareze et al, 2019); residual stresses may be induced throughout porcelain veneer and influence the bond-strength between them (Gostermeyer et al, 2010). Therefore, this study aims to evaluate the effect of different zirconia thicknesses on the shear bond strength with a porcelain veneer.

Material and Methods
Zirconia specimen's preparation
Zirconia blank was marked with a pencil and sectioned with a cutting saw to form cubic shape specimens. Each specimen was glued into a custom made the fitting pin, and then it was seated in the milling machine. The handpiece with a diamond cutting disc running at a high speed of 20.000 rpm after its securing to a movable holder of milling machine for free-movement along the side of the zirconia specimen to trim its shape from cubic to cylinder. The same cutting disc was also used to cut the zirconia horizontally to form a disc shape specimen, figure (1). A larger dimension was used to compensate for about 20% of firing shrinkage, figure (2). Finally, all zirconia specimens and according to manufacture instruction were sintered in a zirconia furnace (VITA ZYRCOMAT 6000 MS) at 1450ºC for 80 mins.
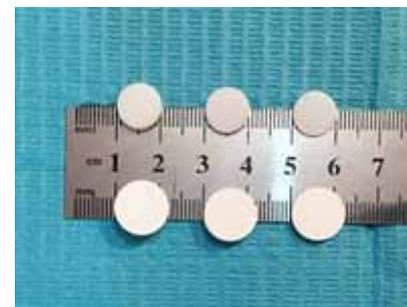

Figure (1): Milling of zirconia specimens.

Figure (2): Final shapes of zirconia specimens before and after sintering.

Specimens grouping
A total of twenty-one (21) disc shape zirconia specimens were prepared with a diameter of 10 mm, (Tabatabaian et al, 2019), and then divided into three groups according to the thickness of 1, 2, and 3 mm, (n=7). These discs and according to manufacturer instruction of porcelain buildup were veneered with cylindrical porcelain of 5×3 mm in diameter and height respectively, (Mosharraf, 2011).

Application of porcelain veneer on zirconia surface
Before the application of the porcelain veneer (Vita VM9, base dentin, 0M1), a thin layer of aqueous mixture layer (Washbake) was applied in a thin layer to the dry clean zirconia surface by using a fine brush. Then, according to manufacture instruction, the firing takes place in a zirconia furnace. To obtain the desired dimensions of veneering ceramic, a custom-made metal mold was made for the application of por-

celain at a controlled thickness of 5 mm in diameter, and 3mm in height by using the layered-technique. The porcelain powder and modeling liquid (VITA, Germany) were mixed to produce the desired creamy consistency of ceramic. Then the ceramic was added into the mold using a brush. The excess liquid was blotted with a tissue and the veneering technique continued till the mold filled. The first sintering was performed according to manufacture instructions. Yet, due to volumetric contraction during porcelain sintering, the second layer of dentin (VitaVM9, base dentine 0M1) and enamel porcelain layer (Vita VM9, Enamel ENL) were used in the mold and then vibrated, dried, and then fired according to the manufacturer instructions. After complete firing, the dimensions of the veneering ceramic were measured by digital Vernia, and then adjusted by using a straight handpiece and diamond bur. Finally, the glazing layer was applied and fired following the manufacturer's instructions.

Preparation of specimens for testing
All zirconia specimens for shear bond strength bonded onto a type IV hard stone block according to both studies by (Saka and Yuzugullu, 2013; Lee et al, 2016). A custom-made square silicon mold was also used for the construction of these stone blocks. The block has a dimension of 20×20mm length and width respectively. After that, all the specimens were glued with cyanoacrylate resin (UHU Epoxy, Germany) and then fixed on the stone block without applying any pressure, then left for 24h for drying and complete polymerization.

Shear bond strength test
For the shear bond strength test procedure, the specimen was fixed tightly to the lower jaw of the testing machine. The application of load was parallel to the long axis of the specimens and at porcelain-zir-conia interface, with a chisel-shape shearing rode at a constant crosshead speed of 1 mm/min up to failure (Fischer et al, 2009). The maximum force was recorded in (N), and the shear bond strength in (MPa) was considered by dividing the load (N) by the surface area of bonded area (mm2) following this formula: Shear bond strength (SBS) in MPa = force in (N)/ surface area (SA) in (mm2), (Daud et al, 2017).

Statistical Methods
The study data analyzed via One-way ANOVA and LSD test at a confidence level of 95% and a significant P-Value of ($p \leq 05$).

Results
In figure (3), the highest shear bond strength mean value was noticed in the group (C3), while the lowest mean value of the shear bond strength was in the group (C1). In table (1), One-way ANOVA revealed that there was a high significance in shear bond strength among (C1, C2, and C3), LSD in the table (2) showed that there was a significant difference between (C1) group with (C2) group, and between (C2) group and (C3) group, also there was a highly significant difference between (C1) and (C3).
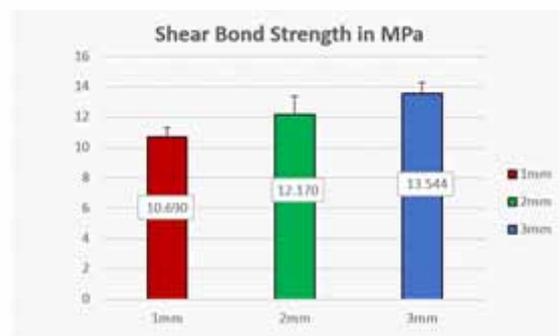

Figure (3): Bar chart for means ofgroups.

Table (1): One-Way ANOVA test for shear bond strength among 1, 2, and 3 mm thickness of zirconia groups.

	F-test	P-value	Sig.
Between group	17.691	0.000	HS

Table (2): LSD test among 1, 2, and 3 mm thickness of zirconia groups (C1, C2 and C3).

Study Groups of Zirconia (thickness)		Mean Difference	Std. Error	p-value	Sig.
1 mm	2 mm	-1.48029-*	.47996	.006	S
	3 mm	-2.85429-*	.47996	.000	HS
2 mm	3 mm	-1.37400-*	.47996	.010	S

Discussion

Different zirconia thicknesses could interfere with some properties of porcelain because of the low thermal diffusivity and conductivity of zirconia compare to the metal (Lungareze et al, 2019). The relationship between the thickness of Y-TZP and the thermal conductivity is may in reverse, that's mean when porcelain veneer fired on different zirconia core thickness may not receive homogenous heat, as porcelain veneer fired on thicker zirconia received less heat. Whereas, the porcelain veneer fired on thinner zirconia could receive more heat (Alwthinani, 2016). The firing schedule of porcelain reaches the maximum temperature in the range between 750ºC-1000ºC, and the ceramic becomes in a plastic state (Almeida Junior et al, 2017). During the cooling of porcelain, the physical properties of porcelain start to change, and the transition starts from the viscous-elastic state at an area above the glass transition temperature (Tg) to solid-state at the area below the glass transition temperature (Tg). As a result, thermal-residual stresses may occur along with the veneering porcelain as a function of cooling rate (Fischer et al, 2007; Al-Amleh et al, 2014) and without the application of external load (Mainjot et al, 2012b). Such residual stresses may occur throughout the veneering porcelain either by a mismatch in thermal expansion or by thermal gradient formed throughout cooling, or both (Paula et al, 2015). The temperature gradient may be affected by the cooling rate, thickness, and thermal conductivity of both porcelain and zirconia (Guazzato et al, 2010). Lately, one of the published studies explained that the bond strength between the layers of the bilayered system is highly affected by thermal residual stresses (Taskonk et al, 2005).

The findings of the present study could be explained that the thicker zirconia of 2 and 3mm conserve more heat than that of a thinner zirconia with 1mm thickness, and consum time to reach room temperature. The impact expected would be similar to slow cooling, while thinner core would be similar to rapid cooling (Lungareze et al, 2019). According to the manufacturer instructions, the long-term cooling of veneering porcelain is started at 600ºC (Vita, Germany).

During the rapid cooling protocol of the thinner restoration of 1mm thickness the external surface of the veneering porcelain becomes hard first and begins to contract the result in compressive stresses. Whereas the internal surface remains in the viscous-elastic state and at extreme temperature resulting in high tensile-stresses when the system reaches room temperature (Paula et al, 2015). This technique is expected-given that the temperature of the internal surface of veneer porcelain still above its glasses transition temperature (Tg) leading to the temperature gradient (the differences between the internal and external temperature), (Swain, 2009). As a result, thermal-residual stresses could be blocked within veneering porcelain (Baldassarri et al, 2012; Meira et al, 2013).

On the other hand, during the slow cooling protocol of the thicker restorations of 2 and 3mm thickness, the veneering porcelain seems elastic when the furnace has been opened. At a temperature of 600ºC below the glass transition of the porcelain (Theoly et al, 2011), the external surface of the veneering porcelain may show no solidification behavior at first. This may due to the absence of a temperature gradient between the internal and external surfaces of the crown. Consequently, no residual thermal stresses may exist in the crown because of relaxation due to viscosity flow (Paula et al, 2015). Also, the residual stresses in the veneering porcelain were closely related to the chipping failure and that slow cooling might reduce the amount of tensile residual stresses (Tang et al, 2017).

Since the cooling rate adopted in the present study was not considered as a variable, but, it could be assumed that the thermal gradient in the specimens with different thicknesses might have been affected differently to impact the residual thermal stresses (Belli et al, 2012, Tan et al, 2012). The positive effect of slow cooling may have an improvement effect on the shear bond strength between zirconia of 2.7 mm thickness and porcelain veneer. The interface between veneering porcelain was different in concern to the cooling rate. In slow cooling, smaller porosities are presented at the porcelain interface in the veneering porcelain, while rapid cooling shows numerous large porosities in numbers and sizes (Komine et al, 2010). On the other hand, slow cooling may provide a negative effect on the shear bond strength between veneering porcelain and zirconia, as structure relaxation in veneering porcelain may occur and lead to the generation of tensile stresses (Göstemeyer et al, 2010; Almeida-Júnior et al, 2013). Moreover, as the thickness of the substructure of 100% from 0.3 to 0.6 mm in-

creasing, the tensile stresses would be reduced by 42% respectively. Furthermore, as this substructure thickness percentage increase with an additional 50% from 0.6 to 0.9 mm, the stresses also decrease by another 49% respectively (Proos et al, 2003). These results may in agreement with (Mainjot et al, 2012a). They state that during cooling, a vertical thermal gradient may occur and could exceed 200ºC in a sample with a typical thickness of 0.7mm with veneering thickness of 1.5mm from the surface to the crown inner, as it possible that the temperature may exceed the Tg temperature of the veneer in some areas locking stresses into porcelain. This could in agreement with (Mainjot et al, 2012b; Lima et al, 2013). They stated that the 1:3 zirconia to veneer ratio cause early cracks showing that a large amount of porcelain veneer may cause shrinkage and generated tensile-stresses which could be perpendicular to the zirconia substructure. As a consequence of the thermal gradient, a thicker layer of the porcelain should be avoided because it may reduce the veneering resistance. After all, if the veneering porcelain becomes thicker, the brittleness may determine the future chipping and fracture behavior in performance (Al-hasanyah et al, 2013).

Conclusion
Within the limitations of the present study, the increase in zirconia thickness with 2 and 3 mm may have the ability to improve the shear bond strength (SBS) between the veneering porcelain and zirconia substructure, however, further studies were needed regarding other properties.

Conflict of interest
We are the author's (Ruaa Qusai Abdul Hadi and Dr.Zahraa Nazar ALwahab) state that the manuscript for this paper is original, and it has not been published previously and it's part of MSc. dissertation and

is not under consideration for publication elsewhere, and that the final version has been seen and approved by all authors.

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