Official Dental Journal of Suez Canal University
DENTAL SCIENCE Updates
Print ISSN 2636-3836
Online ISSN 2636-3844
www.dsujournals.ekb.eg
DSU — Vol. 4, No. 1, March (2023) — PP. 123:129

IN-VITRO EVALUATION OF SHEAR BOND STRENGTH OF DIFFERENT VENEERING MATERIALS TO CAD/CAM ZIRCONIA CERAMICS

Amira Sanad Elsayed [1], Tarek Abdelhamid Abdelhamid [2], Mosaad El Gabarouny [3], Mohamed Osama Atta [4]

DOI: 10.21608/dsu.2023.142221.1128
Manuscript ID: DSU-2206-1128

KEYWORDS

Composite veneer, Lithium disilicate veneer, Shear bond strength, Veneered zirconia.

• E-mail address: jananadeen48@gmail.com

1. Assistant lecturer of Crown and Bridge. Department of Crown and Bridge. Faculty of dentistry. Suez Canal University.
2. Lecturer of Crown and Bridge. Department of Crown and Bridge. Faculty of dentistry. Suez Canal University.
3. Professor of Crown and Bridge. Department of Crown and Bridge. Faculty of dentistry. Suez Canal University.
4. Professor of Crown and Bridge. Department of Crown and Bridge. Faculty of dentistry. Suez Canal University.

ABSTRACT

Introduction: Zirconia ceramics have been widely used as a framework material for all-ceramic restorations. The high crystalline content of zirconia renders the material quite opaque, requiring frameworks to be laminated with a veneering material for optimum color and translucency. **Aim:** The present study evaluated the core-veneer shear bond strength of zirconia-based restorations veneered by four different veneering techniques. **Methods:** Twenty rectangular shaped zirconia blocks (19×15×2mm) were cut from presintered yttria-stabilized zirconia CAD/CAM blocks with a low speed precision cutting saw using water irrigated diamond disk. Sectioned zirconia blocks were cleaned, dried, sintered then assigned to four groups in accordance with the veneering technique (n=5). Finished zirconia blocks were veneered by either fused lithium disilicate discs, bonded lithium disilicate discs, conventionally layered ceramic discs, or composite discs. Shear bond strength test was performed using a computerized universal testing machine. **Results:** Zirconia blocks veneered with fused lithium disilicate discs revealed the highest mean shear bond strength, while the lowest mean value was reported with the zirconia blocks veneered with composite discs. Statistical analysis revealed that differences among all groups showed statistical significance**.** **Conclusion:** Veneering technique and material significantly affected shear bond strength of zirconia-based restorations.

INTRODUCTION

Increased esthetic requirements have led to an enormous increase in the use of ceramic materials for crowns and fixed partial dentures. Partially stabilized tetragonal zirconia by yttrium oxide, has been widely utilized as a high-strength core material for ceramic restorations [(1)]. Zirconia ceramics convey excellent esthetic potential and exceptional mechanical properties expressed by a flexural strength of 900-1200 MPa, elastic modulus of 201 Gpa, and a fracture toughness 7-10 MPa[(2)].

Despite the high strength of conventional yttria stabilized zirconia ceramic, the high crystalline content makes zirconia rather opaque, requiring it to be veneered with an esthetic glass-ceramic for optimal color and translucency. Several veneering techniques were suggested

for veneering of zirconia frameworks by different veneering materials. Conventional porcelain layering, digital veneering techniques in which both zirconia framework and veneer are fabricated using CAD/CAM technology[3] and an indirect composite material for layering on the sintered zirconia framework[4] has been proposed.

Achievement of durable bonding between zirconia cores and veneering materials is a primary requirement for successful veneered zirconia restorations [5]. Several factors have been reported to affect the core-veneer shear bond strength such as flexural strength of the veneering materials, residual stresses owing to thermal mismatch between core and veneering porcelain, surface treatments of zirconia, and structural defects at the core-veneer interface[6]. Thus, the aim of this study was to evaluate the impact of veneering technique and material on core-veneer shear bond strength of veneered zirconia-based restorations.

MATERIALS AND METHODS

Sample size calculation

A minimum calculated total sample size of 20 samples was sufficient to evaluate and compare the effect of veneering technique on shear bond strength of zirconia-based ceramic crowns represented by 5 samples in each group. Kruskall Wallis and Mann Whitney tests were employed for evaluation. The sample size was calculated according to G* Power software version 3.1.9.5.

Preparation of shear bond strength samples:

Shear bond strength between zirconia and different veneering materials were measured as follows:

Preparation of zirconia blocks: 20 rectangular shaped blocks (19×15×2mm) were cut from presintered CAD/CAM zirconia blocks (IPS e-max ZirCAD, Ivoclar Vivadent AG) by a low speed precision cutting saw (Micracut, Metkon, Bursa) using water irrigated diamond disk. The sectioned blocks were rinsed by water to remove milling debris, dried, then sintered in a sintering furnace (Htc Infire speed, Sirona Dental systems, GmbH) at 1500°C for 8 hours. The final dimensions of the zirconia plates after sintering decreased by approximately 25% due to sintering shrinkage of zirconia however this had no effect on shear testing since bonding area of the test samples was confined to the area of the much smaller veneer discs to be bonded to the larger zirconia plates.

Grouping of samples:

The sintered zirconia blocks were assigned to four groups (n=5) according to the veneering material as follows:

Group A: Five zirconia blocks veneered with lithium disilicate discs fused by fusion glass ceramic.

Group B: Five zirconia blocks veneered with lithium disilicate discs bonded by Panavia F2.0 adhesive resin cement.

Group C: Five zirconia blocks veneered with conventionally layered flouroapatite glass ceramic discs.

Group D: Five zirconia blocks veneered with layered composite discs.

Veneering of zirconia blocks:

Fused veneer samples (Group A):

Five lithium disilicate rectangular shaped discs of dimensions (5×6×2mm) were cut out of a lithium disilicate CAD/CAM block (IPS e.maxCAD

Ivoclar Vivadent, AG) using a low speed cutting saw to be fused to zirconia plates using a low fusing glass-ceramic (IPS E.maxCAD Crystall/Connect Ivoclar Vivadent AG). Low fusing glass-ceramic material has a thixotropic property that allows the glass material to turn liquid when vibrated and solidify again in static conditions, after firing in a ceramic furnace the glassy material fuses the ceramic veneer to the zirconia substructures. A special vibrator device with 50 Hz frequency was used for vibrating the material till proper flow was achieved, the mixed material was applied to the pre-crystallized lithium disilicate disc and the disc was seated onto the zirconia block while the material is still flowable. To ensure standardized thickness of fusion glass layer in all samples, the fused disc and block were placed in a loading device with a load of 1kg immediately after seating [7]. After setting of the fusion glass material, each zirconia plate was checked to adhere to its corresponding veneer by the solidified low fusing glass material. Finally, the samples were fused and crystallized in a common fusion crystallization cycle in a special ceramic furnace (Programat P310, Ivoclar Vivadent, AG) according to manufacturer's instructions.

Bonded veneer samples (Group B):

Five lithium disilicate rectangular shaped discs of dimensions (5×6×2mm) were cut out of a lithium disilicate CAD/CAM block (IPS e.maxCAD) using a low speed cutting saw. The discs were crystallized in a separate crystallization cycle then bonded to zirconia blocks by adhesive resin cement (Panavia F2.0 resin cement). Before bonding, the bonding surfaces of all the zirconia blocks were grit blasted with 50μm aluminum oxide particles under 1 bar pressure for 15 seconds at a distance of 10mm, followed by cleaning with distilled water in an ultrasonic bath. The surfaces to be bonded of the lithium disilicate discs were etched for 20 seconds with (7%) hydrofluoric acid washed and air dried, and then a silane-coupling agent was used to coat the surfaces. Equal amounts of pastes A&B of Panavia F 2.0 adhesive resin cement were dispensed and mixed together for 20 seconds. The mixed cement was applied to the disc and seated onto the corresponding zirconia block. Samples were light cured for 3 seconds for initial setting to remove excess cement by a probe and then light curing was carried on for 20 second followed by oxyguard II application to the samples margins. A special device was used to apply and maintain a 3 kg load for 5min on each sample to standardize pressure during cement setting.

Conventional ceramic veneer samples (Group C):

In order to standardize the veneering ceramic thickness with that of the fused or bonded discs, a split silicone index of a finished sample of (group A) was constructed using addition silicone duplicating material and split into two halves using a sharp lancet. To start veneering, zirconia blocks were surface treated by a single layer of IPS e.max Zirliner applied by a brush then each zirconia block was inserted into the split silicon template. The template was assembled and a nanoflouroapatite glass ceramic (IPS e.max Ceram, Ivoclar Vivadent, AG) was applied to fill the window corresponding to the size of the bonded or fused discs. The silicone template was unassembled and the samples were fired in a porcelain furnace. The finished samples were checked in the silicon template, any shrinkage was compensated in a corrective firing cycle. All firing cycles and material applications followed manufacturer's recommendations.

Composite veneered samples (Group D):

The split silicon template constructed by duplication of a fused sample from group A was used to standardize the thickness of the veneering composite disc with the other groups. 110um alumina particles were used to sandblast the sintered

zirconia blocks at 1 bar pressure for 15 seconds then a special bonding agent (SR Link) was applied by a clean brush and left to react for 3 minutes before application of subsequent layer. Indirect veneering composite material (SR nexco Dentin Ivoclar Vivadent, AG) was built up onto the zirconia blocks to fill the window of the assembled silicon template. The finished samples were precured from all directions. Finally, a special masking gel (SR Gel) that is impervious to oxygen was applied to the samples to ensure complete curing and the samples were polymerized directly in a special curing chamber in the recommended cycle for 11 minutes. The finished samples were checked in the full contour silicone index.

All shear bond strength samples were thermocycled for 5000 cycle between 5°C and 55°C in thermostatically controlled water baths. The samples were thermo-cycled with 15 seconds dwell time at each bath and a transfer time of 10 seconds. A specially designed electronic device was used for controlling the thermocycling procedure.

Testing procedures:

Shear bond strength testing among all groups was undertaken by a computerized universal testing machine. For shear bond strength testing, each sample was firmly attached to the lower compartment of the testing machine so that the bonded surface was parallel to the long axis of the machine. Compressive shear test was done using a beveled edge chisel attached to the underside of the upper movable compartment of the testing machine. The chisel edge was placed as close to the interface between zirconia and veneer as possible then a parallel shear force to the interface was applied. The samples were loaded till failure using a 1 mm/min cross head speed. Fracture load was registered and shear bond strength was calculated according to the following equation:

Shear bond strength (Mpa) = fracture load (N) ÷ bonded surface area ($mm^{2)}$.

(Surface area of rectangular discs (length x width) = 5x6=30mm^2)

Statistical analysis of the results was performed.

RESULTS

The mean shear bond strength values (in MPa) of different veneering materials to zirconia and standard deviation are shown in (Table 1) and the mean values presented in a bar chart diagram (Figure 1).

The results revealed that the highest mean value was reported with the zirconia blocks veneered with fused lithium disilicate discs, followed by those veneered with bonded lithium disilicate discs while the lowest mean value was reported with the zirconia blocks veneered with composite build up. Statistical analysis using Kruskal Wallis and Mann-Whitney tests emphasized that there were statistically significant differences among all test groups ($p<0.05$)

Table (1) *Shear bond strength among the four groups:*

Group A	Group B	Group C	Group D	
CAD/CAM veneer (Fusion glass)	CAD/CAM veneer (Panavia F2.0)	Conventional veneer (E.maxCeram)	Composite veneer (SR Nexco)	p-value
19.05 ± 0.83^{a}	16.81 ± 0.33^{b}	14.61 ± 0.45^{c}	12.78 ± 0.31^{d}	0.001*

** Statistically significant difference*
Superscripts indicate statistically significant difference with different pairs of groups.

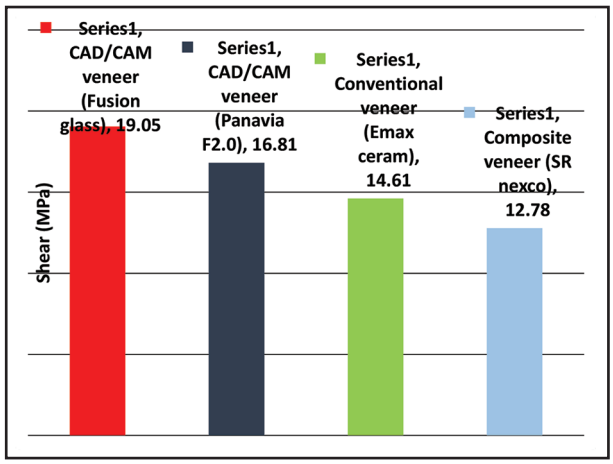

Fig. (1) Bar chart diagram of mean values of shear bond strength among different veneered zirconia groups.

DISCUSSION

Shear bond strength test has been widely used for evaluation of the bond strength between core and veneer of veneered zirconia-based restorations. In the light of explaining the importance of the tensile and shear in vitro tests, Atta [8] stated that "The complexity of the nature of the intra-oral forces raises the question whether the test method is in any way clinically relevant". Atta [8] also reported that "laboratory measurements of shear and tensile bond strengths should give an indication of how the bonded restoration might perform under oral loads".

The design of shear bond strength test samples in this study (rectangular-shaped disc bonded to a zirconia block of larger dimension) was in accordance with literature [9,10]. This design allows better control on bonding procedures and surface area since the bonding area is confined to the area of the bonded veneer. Moreover, this design allowed proper mounting of the sample in the universal testing machine with the long axis of the shearing chisel parallel and very close to the tested interface to ensure application of the shear load on the bonded interface.

Different crosshead speeds may affect the bond strength results probably due to the different loading rates [11]. The crosshead speed range used for the fracture resistance testing of zirconia crowns in the literature varied from 0.5-1 mm/min. In this study a 1 mm/min cross head speed was used during shear bond strength testing as it was considered to be in accordance with literature [7,9,12]. In the present study, the highest recorded value was found with zirconia samples veneered with fused lithium disilicate (group A) which was significantly higher than those veneered with resin bonded lithium disilicate (group B). The significant improvement of shear bond strength of fused samples to zirconia might be related to the bonding performance of the fusion glass interface since both groups were veneered by the same material. Fusion glass ceramic possess high flow due to its thixotropic property which enables the glass material to turn liquid when vibrated. This liquid phase might have flowed into the micro-irregularities of the bonded surfaces providing intimate contact and less structural defects in the core/veneer interface This scientific assumption was inspired from SEM studies [7,9] who found absence of porosities along the interface of fused ceramic samples. Another parameter could be the composition of the employed low fusing glass ceramic being flouroapatite crystals embedded in a glassy matrix. Silica particles of this glassy matrix might have possessed a chemical affinity to those of the glassy matrix of lithium disilicate veneering ceramic forming chemical bonds that might be responsible for improving the surface contact and allowing continuity of the glass phases between the fusing and veneering materials together. Glass particles might have coalesced with glass particles of lithium disilicate ceramic during the common fusion/crystallization firing cycle at 840°C.

On the other hand, the shear bond strength results of bonded lithium disilicate to zirconia using Panavia F2.0 adhesive resin cement (group B) could be attributed to the bonding of MDP monomer of Panavia F2.0 resin cement to the oxide content of the sandblasted zirconia. Hydroxyl groups of zirconium oxide might chemically react with the MDP phosphate ester monomers at the interfacial level [13,14]. In addition, the bonding of Panavia F2.0 resin cement to lithium disilicate should depend on the mechanism of etching which dissolves the glassy component of the silica-based ceramics, silanating that forms a siloxane network, and the high affinity of the adhesive resin cement to bond to this etched and silaned ceramic. However, these bonding mechanisms achieved shear bond strength which was significantly lower than that of the fused samples. This might be related to decreased flow and wettability of ceramic surfaces by the resin cement, absence of the glass phase in Panavia F2.0 resin cement, polymerization stresses induced at the resin/ceramic interfaces during resin cement polymerization, and lower flexural strength of the resin cement than that of fusion glass ceramic (90Mpa versus 160 Mpa).

In this study, zirconia samples veneered with conventional ceramic layering (group C) showed reduced shear bond strength than groups (A&B) which was statistically significant. Shear bond strength of conventionally layered ceramic to zirconia might have been affected by multiple firing cycles which might have created interfacial residual thermal stresses between the core and veneer, this could be aggravated by the wide difference in coefficient of thermal expansion (CTE) of fluorapatite glass-ceramic (IPS E.max Ceram) ($9.8\times10^{-6}/K^{-1}$) and zirconia ($10.8\times10^{-6}/K^{-1}$) since it has been reported that a CTE mismatch of more than ($0.5\text{-}1\times10^{-6}/K^{-1}$) between the core and veneer causes residual thermal stresses within this interface [15]. In addition, presence of air bubbles in the slurry mix and firing shrinkage of the built up ceramic might have initiated interfacial stresses at the core/veneer interface. Finally, brittleness of the veneering ceramic might have also affected the shear bond strength.

The lowest shear bond strength in this study was recorded by zirconia samples veneered with composite (group D). A bonding primer (SR link) was applied to sandblasted zirconia samples in this study before layering of composite material. This primer was claimed by the manufacturer to incorporate a phosphoric acid functional group to react with the sandblasted zirconia and create a passivated stable chemical bond [16]. However, the low shear bond strength of this group, could be related to stresses induced at the composite/zirconia interface during composite polymerization where polymerization shrinkage towards the center might have created micro gaps and structural defects at the interface causing the composite/zirconia interface to be in a preloaded state at which stresses might concentrate during shear testing. Also, the effect of thermocycling might have affected the created bond. The results were in accordance with several studies [17,18,19] who reported reduced bond strength of composite material to zirconia after thermocycling as well as low shear bond strength between composite and zirconia.

CONCLUSIONS

Different veneering techniques and materials of zirconia-based restoration significantly affect core-veneer shear bond strength. Composite veneers have low shear bond strength to zirconia ceramics.

REFERENCES

1. Miyazaki T& Kobayashi T. Current status of zirconia restoration. J Prost Res 2013; 4:236-261.
2. Dellabona A, Pecho OE, Alessandretti R. Zirconia as a dental biomaterial. Materials J 2015; 8:4978-4991.
3. Schmitter M, Schweiger M, Mueller D, Rues S. Effect on in vitro fracture resistance of the technique used to attach lithium disilicate ceramic veneer to zirconia frameworks. Dent Mater 2014; 30:122-130.
4. Komine F, Kobayashi K, Blatz MB, Fushiki R, Koizuka M, Taguchi K et al, Durability of bond between an indirect composite veneering material and zirconium dioxide ceramics. Acta Odontol Scand 2013; 71:457-463.
5. Abrisham SM, Fallah Tafti A, Kheirkhah S, Tavakkoli MA. Shear Bond Strength of Porcelain to a Base-Metal Compared to Zirconia Core. J Dent Biomater 2017; 4:367-372.
6. Tanis MV, Kilicarslan MA, Bellaz IB. In vitro evaluation of bond strength between zirconia core and CAD/CAM-produced veneers. J Prosthodont. 2020; 29:56-61.
7. Zaher AM, Hochstedler JL, Rueggeberg FA, Kee EL. Shear bond strength of zirconia-based restorations veneered with two different techniques. J Prosthet Dent 2017; 118:221-227
8. Atta MO. A comparative study of the bond strength of chemical and mechanical retention systems for direct bonded bridge retainers. 1991 (Ph.D. Thesis) Faculty of medicine, University of london; P193.
9. Kanat-Ertürk B, Çömlekoğlu EM, Dündar-Çömlekoğlu M, Özcan M, Güngör MA. Effect of veneering methods on zirconia framework-veneer ceramic adhesion and fracture resistance of single crowns. J Prosthodont 2014; 24:620–628.
10. Yilmaz S, Necla D, Nilgun O, Hamdi S. Effect of different surface treatments on the bond strength of lithium disilicate ceramic to the zirconia core. Photomed and Laser Surg J 2016; 34:236-243.
11. Hara AT, Pimenta LA, Rodrigues LA. Influence of cross-head speed on resin-dentin shear bond strength. Dent Mater 2001; 14:319-323.
12. Alsadon O, Patrick D, Johnson A, Pollington S, Wood D. Fracture resistance of zirconia-composite veneered crowns in comparison with zirconia-porcelain crowns. Dental Mater 2017; 36:289–295.
13. Kern M. Wegner SM. Bonding to zirconia ceramic: Adhesion methods and their durability. Dent Mater 1998; 14:64-71.
14. Wolfart M, Lehmen F, Wolfart S, Kern M. Durability of the resin bond strength to zirconia ceramic after using different surface conditioning methods. Dent Mater 2007; 23:45-50.
15. Alsulami U, Alshihri A, Huraib W,Alzahrani T, Albakkar H. The effect of coefficient of thermal expansion differences on bond strength of ceramic-zirconia interface. Int J Dent Med Res 2015; 1:1-6.
16. Vivadent I. SR Nexco Indirect Composite Scientific documentation. Schaan, Liechtenstein: Ivoclar Vivadent.
17. Komine F, Fushiki R, Honda J, Kamio S, Blatz MB, Matsumura H. Long-term bond strength between layering indirect composite material and zirconia coated with silicabased ceramics. J Adhes Dent 2015; 17:273-281
18. Hatta M, Shinya A, Yokoyama D, Gomi H, Vallittu PK. The effect of surface treatment on bond strength of layering porcelain and hybrid composite bonded to zirconium dioxide ceramics. J Prosthodont Res 2011; 55:146-153.
19. Sari F, Secilmis A, Simsek I, Ozsevik S. Shear bond strength of indirect composite material to monolithic zirconia. J Adv Prosthodont. 2016; 8:267-274.