10.5005/jp-journals-10019-1211

RESEARCH ARTICLE

A Comparative Evaluation of Shear Bond Strength of Ceramic Fused to Metal Fabricated using Veneering and Pressable Techniques–An *In Vitro* Study

[1]Rahul S Patil, [2]Omkar Shetty

ABSTRACT

Purpose: Evaluation of shear bond strength of ceramic fused to metal fabricated using veneering and pressable techniques.

Material and methods: 10 metal disc samples were prepared in Ni-Cr base metal alloy and divided in two equal groups. Group A: conventional veneering of ceramic on metal-(leucite-glass-ceramic) and group B: pressing of ceramic on metal-(leucite-glass-ceramic). The shear bond strength between ceramic and metal bond was tested using custom-made jig assembly and Instron testing machine. Values obtained were evaluated and compared.

Results: The results of this study showed that the mean bond strength values for veneering ceramic samples were 25.06 MPa which was higher than the mean bond strength values for press ceramic samples which was 21.68 MPa.

Conclusion: Mean bond strengths differed between the two groups, indicating that the fabrication technique has an influence on the bond strength. The mean bond strength values for press ceramic were below the recommended standard International Organization for Standardization (ISO) value of 25 MPa for metal-ceramic bond whereas values for veneering ceramic were in a clinically acceptable range.

Keywords: Instron, Metal ceramic, Pressable, Shear bond strength, Veneering.

How to cite this article: Patil RS, Shetty O. A Comparative Evaluation of Shear Bond Strength of Ceramic Fused to Metal Fabricated using Veneering and Pressable Techniques–An *In Vitro* Study. Int J Prosthodont Restor Dent 2018;8(3):84-90.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Since its introduction in the 1950s, the ceramic fused to metal restoration, have been playing an essential role in restorative dentistry. They allow efficient restorations with great color stability and fracture resistance which is provided by the metallic framework.[1] However, ceramics could only be used with specific metal frameworks because of mismatches in the ceramic fusion and alloy casting temperature differences in the coefficient of thermal expansion (CTE) of the two substrates.[2] For the clinical success of metal-ceramic restorations, the development, and understanding of an optimal bond between ceramic and metal substructure was essential. Although various theories and concepts have been proposed for the actual mechanism of bonding, it remains elusive.[3]

Good results of metal-ceramic restorations depend not only on the characteristics of the metal and ceramic but also on the processing technique used. Two commonly used techniques are veneering technique and pressable technique. Veneering technique, however, requires multiple firing cycles leading to contraction and also a reduction in strength. To overcome these problems, pressable or pressed ceramic was introduced with a single or two-stage firing.

Recently, the development of a low-fusing pressable leucite-based glass ceramic, compatible with porcelain fused to metal (PFM) alloys in both processing temperature and CTE, has allowed for its merging with the traditional strength of the alloy framework.[4] Pressed ceramic systems, have a wide array of ceramics that are comparable to feldspathic systems. Now with the development of press on technique, various new ceramics can be used but does this technique allow stronger metal-ceramic bond than conventional veneering technique is yet to be evaluated. A recent study compared shear bond strength using the similar technique, but laser sintered cobalt chromium alloy was used instead of nickel chromium. The investigation revealed that bond strength for heat pressed porcelain to laser sintered co-cr alloy was higher than the conventional veneering technique.[5]

The current study is designed to evaluate and compare the shear bond strength of leucite ceramics bonded to metal using veneering technique and pressable technique.

MATERIALS AND METHODS

The current study was performed at Department of Prosthodontics at Dr D.Y. Patil Dental College and Hospital, Navi Mumbai. For fabricating of metal discs, crown wax pattern of dimension 14 mm × 8 mm was

[1]Specialist Dentist, [2]Professor and Dean

[1]Department of Prosthodontics, Ministry of Health, Specialized Dental Center, Ras Al Khaimah, United Arab Emirates

[1]Department of Prosthodontics, Dr D.Y. Patil Dental College and Hospital,Navi Mumbai, India

Corresponding Author: Rahul S Patil, Specialist Dentist, Department of Prosthodontics, Ministry of Health, Specialized Dental Center, Ras Al Khaimah, United Arab Emirates, e-mail: drrahulprostho@gmail.com

fabricated in the number 2 bar of the sliding jig assembly (Fig. 1). The pattern was sprued and invested in phosphate bonded investment material (I-Calibra Express, Protechno, Vilamalla Girona, Spain). Ni-Cr ceramic base metal alloy (Ruby mwa; Ruby dental products, Osaka, Japan) containing Ni–76.0%, Cr–14.0%, Mo–6.0%, Be–1.8%,Al–2.0% was used for casting to fabricate 10 metal discs (Fig. 2). IPS Inline system opaquer paste was applied on the finished metal discs and transferred to a sagger tray and placed near the open muffle of the ceramic furnace (Programmat P500; Ivoclar vivadent; Bendererstrasse, Schaan) to sinter the opaquer. All ten discs were masked with opaquer in a similar manner and then divided into two groups of five samples each and were named as group A: IPS InLine veneering ceramic and group B: IPS InLine PoM press ceramic.

The samples of group A were layered with IPS InLine veneering ceramic (Ivoclar Vivadent; Bendererstrasse, Schaan) which is a leucite ceramic based on calci-alumino silicate glasses and feldspar which was mixed with IPS InLine liquid. Firing was done at 910°C for sintering the samples. The composition of veneering ceramic was as follows (in weight %)–SiO_2 59.5–65.5, Al_2O_3 13.0–18.0, K_2O 10.0–14.0, Na_2O 4.0–8.0,other oxides 0.0–4.0, pigments 0.0–2.0. The sintered sample was measured using a measuring scale to confirm the dimensions of ceramic build up to be of 14 mm × 4 mm. So each metal ceramic sample measured 14 mm × 12 mm that is 8mm of metal height and 4mm of ceramic built up above it. All 5 discs of Group A were fabricated in a similar manner using the veneering technique[6] (Fig. 3).

For group B samples, complete contour wax pattern using IPS press wax (organic wax) was used to fabricate pattern of dimension 14 mm × 4 mm on the opaqued metal disc. The wax pattern was sprued and invested. The casting ring was placed in a burn out furnace at 700°C for 20 minutes. The heated casting ring was carried to the Empress-pressing machine. The IPS InLine PoM ingot which is a leucite ceramic based on calci-alumino silicate glasses with the following composition (in weight %): SiO_2 50.0–65.0, Al_2O_3 8.0–20.0, Na_2O 4.0–12.0, K_2O 7.0–13.0, other oxides, fluoride 0.0–6.0, pigments 0.0 –3.0, was placed with the imprint facing upwards in the funnel of the casting ring in the Empress pressing machine.[7] The heat pressing cycle was carried out at 915°C for 18 minutes followed by cooling for half an hour (Fig. 4).

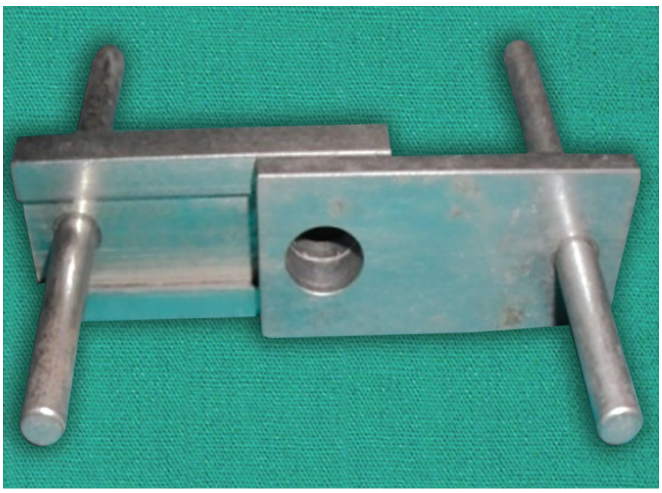


Fig. 1: Customized sliding jig assembly


Fig. 2: Finished metal discs

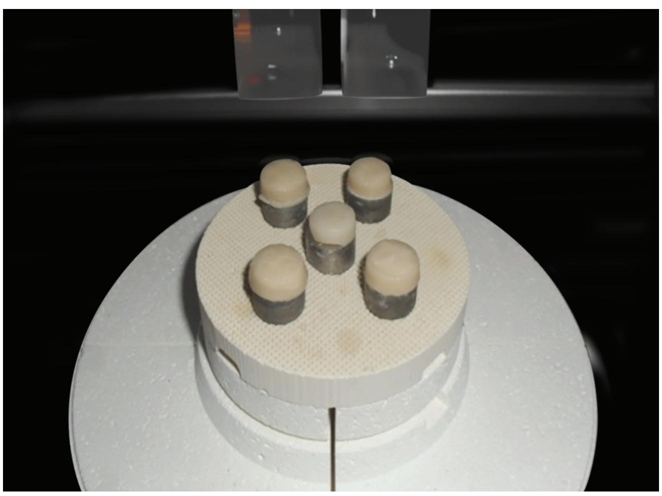


Fig. 3: Group A–Final samples using the veneering technique

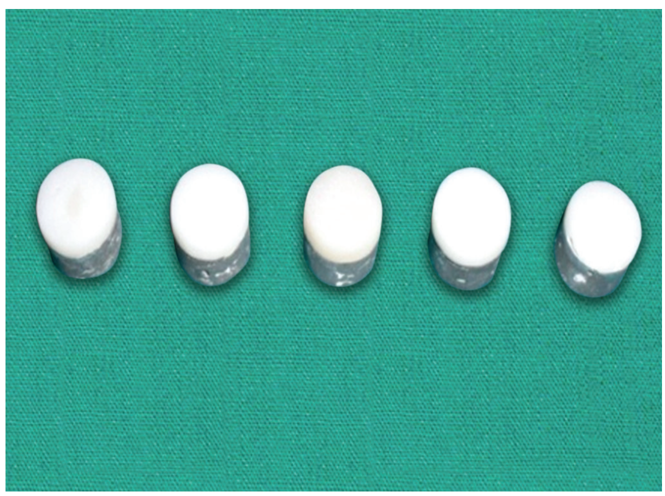


Fig. 4: Group B–Final samples using press technique

A custom made sliding jig assembly was used for circular interface shear test. It was attached to the Instron universal testing machine 5960 dual column tabletop model to provide a repeatable method of introducing shear stress at the interface between the metal and ceramic.[8] The jig was made up of two horizontal metal bars no. 1 and no. 2 of dimensions 7 cm × 3.5 cm (l × b) which were able to slide over each other and interlocked with the dovetail-shaped sliding mechanism. The no. 1 bar had the horizontal dovetail shaped depression for the no. 2 bar dovetail to slide into it horizontally. The height of the no. 1 bar was 8 mm, and the no. 2 bar was 4 mm. Each of the bars had an aperture of dimension 14 mm at one end and another small aperture of 8mm at opposite end. The dimension of larger aperture in the no. 1 bar was 14 mm × 4 mm, and the smaller aperture was 8 mm × 4 mm. Similarly, the no. 2 bar had a larger aperture of 14 mm × 8 mm and smaller aperture of 8 mm × 8 mm. So when the jig assembly was made to slide over each other from opposite ends, the holes could coincide at a point.[9] The smaller aperture was made so that cylindrical bars could pass through at each end and get attached to the clips of the Instron machine and help pulling the assemblies away from each other. An additional small horizontal aperture was made on the lateral aspect of one assembly through which a screw was placed and tightened so that it could touch the lateral aspect of the sample and secure the samples in position. The Instron machine with a crosshead speed of 5 mm/minute was then gradually loaded until the load-deflection curve of each sample showed a sudden deviation on the digital chart, indicating bond failure which occurred at the metal-ceramic interface.[10] Measurements were recorded for the increasing loads which were applied progressively. A similar procedure was followed for all samples (Fig. 5). The samples were observed to de-bond at a range of specifically applied loads. Data gathered was analyzed, and shear bond strength was calculated in N/mm^2 using formula–

Bond Strength = Force/Area =
Load/Area = KgF/πr=7.5 mm)

The observations were statistically analyzed to comparatively evaluate the values. Student's "t" test was used to analyze and compare group A with group B.

RESULTS

The results of the test were tabulated in Tables 1 and 2 depicting the shear bond strength values for samples of groups A and B respectively. Statistical values were tabulated in Table 3. Graph 1 was tabulated which represented the mean values of the shear bond strengths of both groups.

The null hypothesis was that there is no significant difference between the mean shear bond strength of metal and ceramic when fabricated using veneering ceramic and pressable ceramic technique with p = <0.005. The alternate hypothesis derived was that there is a significant difference between the mean shear bond strength of metal and ceramic when fabricated using veneering ceramic and pressable ceramic technique. The Independent t-test results (p value = 0.086262 > 0.05) were not significant. This indicates that there was no strong evidence to reject the null hypothesis. Therefore it was concluded with the comment that there was no significant difference between the mean shear bond strength of metal and ceramic when fabricated with veneering ceramic and pressable ceramic technique. The difference so far observed may be a chance difference and both

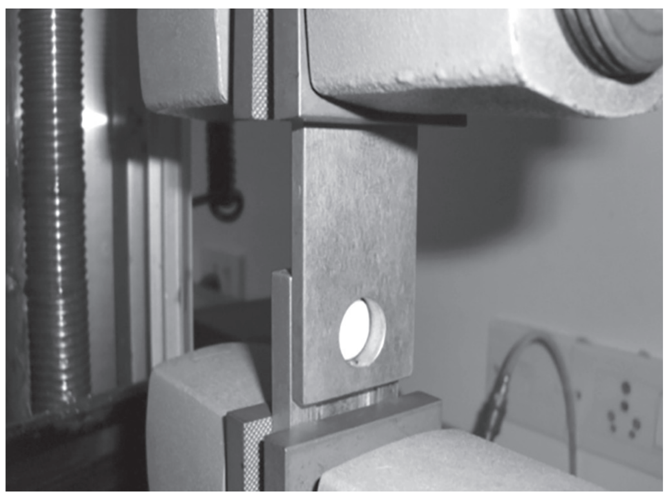


Fig. 5: Testing of samples using jig and Instron machine

Table 1: Group A–(Inline–veneering technique)

Samples	*Load in KgF*	*Shear Bond Strength in MPa*
1	475	26.6
2	492	27.55
3	385	21.56
4	402	22.52
5	484	27.10
AVG	447.6	25.06

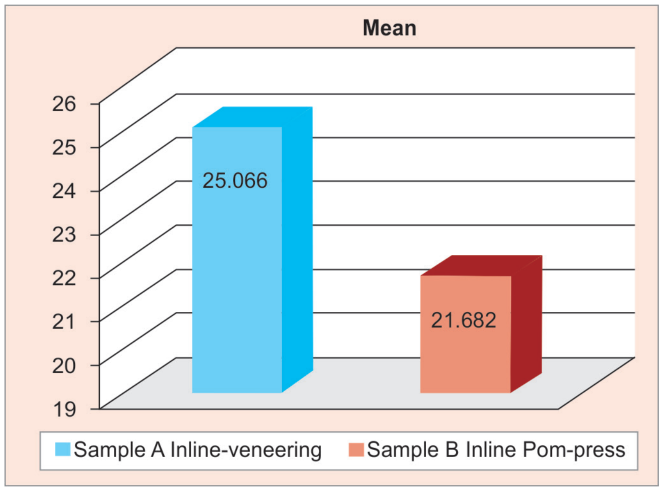
Table 2: Group B–(Inline Pom–press on metal technique)

Samples	*Load in KgF*	*Shear Bond Strength in MPa*
1	321	17.97
2	391	21.90
3	404	22.62
4	451	25.25
5	369	20.67
AVG	387.2	21.68

Table 3: Student's t-test to compare shear bond strength between two group

	Sample A–Inline	*Sample B–Inline POM*
Mean	25.066	21.682
Variance	7.85868	7.11527
Observations	5	5
Degrees of freedom	8	
t -calculated value	1.955452	
P-Value	0.086262	
t –table value	2.306004	

veneering and press on metal show almost equal shear bond strength.



Graph 1: Mean values of shear bond strengths of group A (veneering technique) and group B (press technique)

DISCUSSION

To overcome the shortcomings of feldspathic ceramic, high expansion metal ceramics were developed by raising the coefficient of thermal expansion of feldspathic ceramic to match the values of gold alloys. Feldspar is not present in the final processed ceramic, and the increase in thermal expansion of ceramic occurs due to crystallization of leucite. Hence these high-expansion ceramics are also called leucite ceramics. They are available as conventional sintered powder systems for veneering and in ingot form for heat-pressing using the lost wax technique. Consequently, it is claimed that the strength values can surpass those of layered structures.[11]

Several methods of fabricating metal ceramic restorations have been developed. Conventional veneering system is still the most popular as it is easier to use, less equipment is required, and shade can be controlled from the addition of the first ceramic layer. The drawback of this technique is that the outcome of the prosthesis is dependent on the skills of the operator as it is very technique sensitive and time-consuming. Furthermore, there are problems of firing shrinkage after each stage of sintering. All these lead to the development of newer methods of fabrication of metal, ceramic crowns. The press ceramic technique is one such recent popular technique. The hot-pressed ceramic technique provides a method of fabricating full occlusal-coverage ceramic-fused-to-metal restorations. Using this technique, a waxed restoration can be processed in ceramic with accurate occlusal details that previously could be attained in only metal or acrylic resin. Pressable ceramic systems use the lost wax technique, which eliminates the need for multiple firings and potential marginal changes seen during conventional sintering techniques. After the opaquing stage, a full contour wax pattern is fabricated and invested, and ceramic is pressed onto the undercasting.[12]

The advantages of using press technique are: the possibilities are unlimited, platinum foil is not necessary and alumina profiles metal posts and attachments can be accurately inserted, an exact marginal seal is possible, the technique for making a fixed partial denture is simple, compressed ceramic units are very strong, ceramic furnace is required which will permit compression of the ceramic restoration at elevated temperatures and this technique is also slightly expensive than the conventional veneering techniques.[13,14]

Various theories and techniques by using resin bonding materials and by surface conditioning and chemical etching methods have been proposed over the years for improving metal to ceramic bond. This bond is important as during occlusal loading the ceramic can chip off from the metal.[15] Even though studies reveal that shear bond strength was almost the same for veneering ceramics to high noble alloy using both the techniques, research needs to be carried out for ceramic fused to base metal alloys.[16]

Even after the development of various metal ceramic fabrication techniques, there is still a lack of literature claiming which technique provides a better ceramic to metal bond. So the present study was planned to evaluate the metal-ceramic bond strength for leucite ceramic, fabricated using veneering and press technique,[17] and it is highly reliable because it is based on minimal experimental variables and the least residual stresses at the metal-ceramic interface.

The results of the present study showed that the mean bond strength values for veneering ceramic samples were 25.06 Mpa and for ceramic press samples were 21.68 Mpa and statistically there was no significant difference. The debonded samples were visually evaluated, and few samples showed separation of entire ceramic from metal along with the opaque, few samples demonstrated debonding at the junction of opaquer and few samples showed debonding within the ceramic itself. Types of failures were grouped into adhesive failures and cohesive failures (Figs 6 and 7).

There can be several reasons for these varying patterns of bond failures. They can be classified into three main factors that determine the success of a ceramic-metal bond; they are–Residual stress gradients, interfacial chemistry, and interfacial morphology. Much of the basic research has concentrated on residual stresses and thermal expansion compatibility. With significant differences in thermal expansion coefficients, residual stress gradients from across the interface during processing. These stresses can be so strong that either the bond fails at a much lower stress level or the ceramic spontaneously spalls off. Generally, we attempt to limit differences in thermal expansion coefficients between the ceramic and the metal. Theories of the effects of interfacial morphology have been mixed. Some researchers believe that rough interface morphologies improve bond strength by mechanical attachment or by increased area for chemical bonding. However, others believe that roughness can weaken the interface by causing stress concentrations that could initiate fracture and others believe that roughness could cause incomplete contact between the metal and ceramic (and trapped gases), which could also reduce bond strength.[18]

Mechanical failures of metal-ceramic systems are not surprising considering the vast differences in modulus between the metal and ceramic materials.[19] During cooling, the leucite crystals contract more than the surrounding glass matrix leading to the development of tangential compressive stresses around the leucite particles as well as micro cracks within and around the crystals.[20]

The group A samples (veneering) in this study exhibited more of the cohesive type of failures. Many of the samples exhibited debonding within the ceramic itself. Nearly all veneering samples showed ceramic residues on the surface of the metal which exhibited signs of cohesive failure. The reason for such failure could be a higher adhesive bond strength between ceramic and metal than the cohesive bond between ceramic. But there are possibilities of dust and impurities getting incorporated while using the veneering technique as ceramic is not applied under vacuum. These impurities could have caused voids, adversely affecting the bond leading to adhesive failures. Another reason for this type of failures could be the incremental addition of ceramic and subjected to repeated sintering for compensating of the firing shrinkage after the addition of each layer of ceramic. This could have weakened the cohesive bond between ceramic. For InLine ceramic, cooling to 700° C or 800° C is recommended in conjunction with main firings. Failure to achieve this could affect the bond strength. It has been seen that shear bond strength measurements were very sensitive to the method of preparation of the specimens and the design of the testing arrangement

The press ceramic samples exhibited more of adhesive failures. Most of the specimens for press ceramic IPS InLine PoM exhibited areas of exposed metal. Some of the specimens exhibited areas of opaque ceramic. These interfacial failures were visible by fragments of nearly entire ceramic getting de-bonded and separated from metal after testing with minimal opaquer residues on the metal interface. The reason for this could be epitaxial stresses which may also arise at the metal-ceramic interface even with very thin oxide layers. Such stresses may cause a reduction or loss of adherence and consequently may result in weaker bond strength. Due to the pressing of a large mass of ceramic on metal, there could be a possibility of improper condensation leading to voids and thus

Fig. 6: Group A debonded samples

Fig. 7: Group B debonded samples

weakening the metal-ceramic bond. However, if the roughness of a surface causes voids at the interface, which could have been possible with press ceramic samples due to the presence of wax residues, adhesion could have decreased. In a recent study, it was found that sintered metal alloy for computer-aided manufacturing (CAD-CAM) exhibited shear bond strength to ceramic comparable with cast metal alloys and hard milled alloy either ceramic application by ceramic pressed-on technique or ceramic layering technique.[21]

The ceramic pressed-on technique significantly provided higher metal-ceramic bond strength for metal-ceramic restorations than that of a conventional layering technique. It is suggested that the heat pressed technique is recommended in ceramic application to the dental alloy. The sintered alloy is more preferable selection for metal ceramic restoration since it exhibited a suitable survival probability as well as reliable shear bond strength compared to others. The reported effects of surface roughness on metal-ceramic bond strength are difficult to interpret because the degree of surface roughness is either not defined or sparsely used in dental laboratories.[22] Crowns made using the conventional IPS InLine technique showed 45% greater fracture resistance than IPS InLine PoM made with the press-on technique.[23]

The fabrication technique had influenced the bond strength in the present study. The mean bond strength values for press ceramic were also below the recommended standard ISO value of 25 MPa for metal-ceramic bond whereas values for veneering ceramic was in a clinically acceptable range.

LIMITATIONS

The shear test used in this study may not represent the clinical environment to which a metal-ceramic restoration is truly subjected to the direction of the occlusal forces. Accurate measurements of bond strengths at metal-ceramic interfaces have elicited several questions because the complexity of the bonding mechanism currently defies the development of individual test design.

CONCLUSION

Within the limitation of the study, the following conclusions were drawn:

- Metal ceramics fabricated using the veneering technique exhibited higher bond strength. However more of cohesive failure within the ceramic was observed.
- Metal ceramics fabricated using press technique exhibited lower bond strength. However, more of adhesive failure between ceramic and metal was observed.
- Bond strength values of metal ceramics fabricated using veneering technique were higher than the ones fabricated using Press technique.
- Bond strength values of metal ceramics fabricated using veneering technique were above the recommended standard ISO value and those fabricated by press technique were slightly below the commended standard ISO value.

REFERENCES

1. Scolaro JM, Valle AL. Bonding ceramic to metal: a comparison using shear tests. Rev Fac Odontol Bauru. 2002;10(1):57-62.
2. Schweitzer DM, Goldstein GR, Ricci JL, Silva NR, Hittelman EL. Comparison of bond strength of a pressed ceramic fused to metal versus feldspathic porcelain fused to metal. J Prosthodont. 2005 Dec;14(4):239-247.
3. Bagby M, Marshall SJ, Marshall Jr GW. Metal ceramic compatibility: a review of the literature. J Prosthet Dent. 1990 Jan 1;63(1):21-25.
4. Johnston JF, Dykema RW, Cunningham DM. The use and construction of gold crowns with a fused porcelain veneer—A progress report. J Prosthet Dent. 1956 Nov 1;6(6):811-821.
5. Pradhan SK, Nadgere JB, Ram SM. A Comparative evaluation of shear bond strength of layered veneering and heat-pressed porcelain to laser-sintered cobalt–chromium alloy: An *in vitro* study. J Contemp Dent 2018;8(1):1-7.
6. Hammad IA, Goodkind RJ, Gerberich WW. A shear test for the bond strength of ceramometals. J Prosthet Dent. 1987 Oct 1;58(4):431-437.
7. McPhee ER. Hot-pressed porcelain process for porcelain-fused-to-metal restorations. J Prosthet Dent 1975 May;33(5): 577-581.
8. Dos Santos JG, Fonseca RG, Adabo GL, dos Santos Cruz CA. Shear bond strength of metal-ceramic repair systems. J Prosthet Dent. 2006 Sep 1;96(3):165-173.
9. Hammad IA, Goodkind RJ, Gerberich WW. A shear test for the bond strength of ceramometals. J Prosthet Dent. 1987 Oct 1;58(4):431-437.
10. Malhotra ML, Maickel LB. Shear bond strength in porcelain-metal restorations. J Prosthet Dent 1980 Apr;43(4):397-400.
11. Seghi RR, Denry IL, Rosenstiel SF. Relative fracture toughness and hardness of new dental ceramics. J Prosthet Dent. 1995 Aug 1;74(2):145-150.
12. Dong JK, Luthy H, Wohlwend A, Schärer P. Heat-pressed ceramics: technology and strength. Int J Prosthodont. 1992 Jan 1;5(1):9-16.
13. Droge GGJ. The porcelain press technique. J Prosthet Dent. 1972;Aug;28:209-214.
14. McPhee ER. Hot-pressed porcelain process for porcelain-fused-to-metal restorations. J Prosthet Dent 1975 May;33(5):577-581.
15. McLean JW. Ceramics in clinical dentistry. British Dent J 1988 Mar;164(6):187-194.
16. Ishibe M, Raigrodski AJ, Flinn BD, Chung KH, Spiekerman C, Winter RR. Shear bond strengths of pressed and layered veneering ceramics to high-noble alloy and zirconia cores. J Prosthet Dent. 2011 Jul 1;106(1):29-37.
17. Hammad IA, Talic YF. Designs of bond strength tests for metal-ceramic complexes: review of the literature. J Prosthet Dent. 1996 Jun 1;75(6):602-608.

18. Wagner WC, Asgar K, Bigelow WC, Flinn RA. Effect of interfacial variables on metal-porcelain bonding. J Biomed Mater Res. 1993 Apr;27(4):531-537.
19. Hasselman DP, Fulrath RM. Proposed fracture theory of a dispersion-strengthened glass matrix. J Am Ceram Soc. 1966 Feb;49(2):68-72.
20. Denry IL, Rosenstiel SF, Holloway JA, Niemiec MS. Enhanced chemical strengthening of feldspathic dental porcelain. J Dent Res. 1993 Oct;72(10):1429-1433.
21. Juntavee N, Oeng SE. Shear bond strength of ceramic fused to CAD-CAM milled alloys. J Dent Res. 1993 Oct;72(10):1429-1433.
22. Wagner WC, Asgar K, Bigelow WC, Flinn RA. Effect of interfacial variables on metal-porcelain bonding. J Biomed Mater Res. 1993 Apr;27(4):531-537.
23. Solá-Ruiz MF, Agustín-Panadero R, Campos-Estellés C, Labaig Rueda C. Post-fatigue fracture resistance of metal core crowns: Press-on metal ceramic versus a conventional veneering system. J Clin Exp Dent. 2015 Apr;7(2):e278-e283.