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Evaluation of shear bond strength of porcelain to metal and zirconia cores: An in-vitro study

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***Abstract*---**Aim: The aim of the study is to find out the difference between the shear bond strength values and failure pattern between the metal ceramic system and zirconia core veneering system. Materials and methods: A study was conducted to find out the difference between the shear bond strength values and failure pattern between the metal ceramic system and zirconia core veneering system. A total of 30 samples were divided into three groups. The first group contains metal core(Ni-Cr base metal-10nos), second group contains

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zirconia- Upcera core (10 nos) and third group contains Zirconia-Amman Girrbach core (10nos). All the cores were layered with corresponding porcelain. The specimens were stored under artificial saliva for 24 hours and were subjected to shear bond strength test using Instron Universal Testing machine (Instron, model 3382, Japan). The testing machine's computer software automatically recorded and reported the maximum load at which failure occurred.SEM study was performed to determine the type of failure. Results: The results show that the mean shear strength of group I is higher than that of group II and group III. Two-way Analysis of Variance (ANOVA) showed that there was significant difference between group I and other groups ($p< 0.005$). Post hoc Tukeys showed statistically significant difference ($p< 0.005$) when compared between one group and other two groups. Conclusion: The study reveals significant difference in shear bond strength values between metal ceramic group and zirconia ceramic group, however, no significant difference among zirconia-ceramic groups was found out. Surface analysis of failure modes showed adhesive and cohesive type of failure. Clinical significance: In the quest to achieve superior esthetics, all ceramic restorations were developed as a substitute for metal ceramic prosthesis. The most frequent reason for failure of zirconia FPD’s were delamination or minor chip-off fracture of veneering porcelain. The purpose of this study was to determine if the shear bond strength of all ceramic restoration is sufficient to withstand the occlusal load.

***Keywords*---**metal core, shear bond strength, zirconia core.

Introduction

The quest for combining strength and aesthetics in fixed partial dentures resulted in the evolution of metal ceramics in the 20th century. Metal-ceramic systems rely on the application and firing of a veneering ceramic onto a metal substructure to produce an esthetically acceptable restoration. The use of porcelain fusedto metal was wide spread due to their superior mechanical and biological properties. However, the greater aesthetic demands and the necessity for using more biocompatible materials have prompted the clinicians to look for metal free prosthodontic restorations.[1] The popularity of all ceramic systems increased after the introduction of alumina reinforced dental porcelain. McLEAN and HUGHES in 1965 used a relatively opaque inner core of high alumina content for maximum strength which was surrounded by a combination of body and enamel ceramic. The technique was further developed by improving the fabrication technique of alumina core and use of different oxides such as Magnesium and Zirconium to strengthen ceramics.

Although many types of zirconia-based ceramics are available, Y-TZP displays the highest initial and most favorable long-term strength due to their excellent strength and superior fracture resistance as the result of an inherent transformation-toughening mechanism.[2] The most prevalent cause of zirconia

FPD failures, however, was listed as delamination or slight chip-off fracture of veneering porcelain. In contrast to metal-ceramic FPDs, zirconia FPDs had a much greater rate of veneer fracturesTherefore, one of the shortcomings in layered zirconia-based restorations and a key factor in determining their long-term effectiveness is the bond between core and veneer or the veneer material itself.[3] In view of the conflicting opinions, this study was undertaken to evaluate the shear bond strength of zirconia and metal alloys with their corresponding veneering porcelains.

Aim of the study

The aim of the study is to find out the difference between the shear bond strength values and failure pattern between the metal ceramic system and zirconia core veneering system.

Methodology

An in-vitro study was conducted in CIPET, Chennai (2018) to evaluate the difference in shear bond strength between metal ceramic and zirconia veneer restorations. Thirty samples were prepared and were divided into three groups. Each group contains 10 samples. Group 1 comprises of base metal alloy core while group 2 and group 3 contains zirconia core of two different manufacturers. Ceramic was layered onto the samples as per manufacturers recommendation.

Preparation of the metal core-veneer specimens (Group I)

The bars (4 × 4 × 9 mm) were cast in Ni-Cr base metal ceramic alloy, according to the manufacturer's instructions. The veneering ceramic was built to a thickness of 3mm. Excess porcelain was removed using a diamond bur with a low-speed hand piece.

Preparation of the zirconia blocks (Group II & III)

The blocks were prepared by CAD CAM technology in which blocks were milled to size (4 × 4 × 9 mm) (Fig-1). The blocks were sandblasted with 110 µmAluminium oxide particlesand were steam cleaned. The veneering ceramic was built and the excess veneer was removed to predetermined size. The final dimensions of bars of group II and III were identical to those of group I. (Figure 2). Each bar was embedded in the customized Aluminum mold (15×15×35 mm) using PMMA resin. The core-veneer interface was placed on the same level as the upper plane of the mold using dental surveyor, and the specimens were prepared. Then the specimens were stored in the artificial saliva for 24 hours.

Shear bond strength Test (SBS Test)

The specimens were stressed in shear at a constant crosshead speed of 0.5mm/min until failure occurred using an Instron Universal Testing machine (Instron, model 3382, Japan). The test was carried out at room temperature. The specimen was subjected to force in such a way that shear load was applied close to and immediately over the bonding interface. The load deflection curves and ultimate load to failure were automatically recorded and displayed by the computer software. Shear bond force was recorded in Newtons, and the average shear bond strength (MPa) was calculated by dividing the load (N) at which failure occurred by the bonding area (mm^2).Shear stress (MPa)= Load (N) ÷ Area (mm^2)

SEM analyses

To determine the mode of failure, all the specimens were examined under scanning electron microscope (SEM-Model Hitachi SU8200, Hitachi High Technologies America, Inc)under × 30, × 250 and × 1000 magnifications. All the specimens were subjected to scanning electron microscopic (SEM) study and were not subjected to any sort of treatment prior to scanning.

Statistical analysis

Statistical analysis was carried out using statistical software (SPSS 11.0). The data was analyzed using the one-way analysis of variance test (ANOVA) and the Tukey's multiple comparison test.

Results

The results (Table1) show that the mean shear strength of group I (65.5700MPa) is higher than that of group II (30.0050 MPa) and group III (31.3120MPa).Two-way Analysis of Variance (ANOVA) showed that there was significant difference between group I and other groups ($p< 0.005$) (Table2). Post hoc Tukeys test (Table3) was done to perform the comparison between groups & it showed statistically significant difference ($p< 0.005$) when compared between metal ceramic group (group I) and all ceramic groups (group II &III). These results show that mean shear bond strength of metal ceramic system is higher than that of the all ceramic system. There was no difference in shear bond strength among the two all ceramic system.

SEM analysis

The zirconia group showed mixed cohesive/adhesive failures on SEM (×30) examination (Fig. 4), with only few porcelain fragments remaining attached to the core material. High magnification (×250 & ×1000) SEM pictures of the zirconia group revealed numerous tiny pores in the veneering porcelain (Fig. 4), where fracture started and spread in the veneering ceramics. A thorough inspection revealed that the fracture surface was covered by a thin veneer of porcelain.Mixed cohesive and adhesive failures were visible in metal alloy specimens with porcelain adhered to the loaded side of the core (Fig. 3). But in certain instances, the metal oxide and alloy failed to adhere together, leaving a thin metal oxide layer covering some of the broken surfaces. Porosities were observed in the porcelain used for veneering under high magnification.

Discussion

The combination of strength of metal substructure and esthetic translucency of dental porcelain resulted in great clinical success of metal ceramic prosthesis in the early 20th century. Success of metal ceramic restoration relies on a good bond strength of ceramic to metal. Chemical bonding by an oxide layer is the primary mechanism of interaction between metal and ceramic. The formation of metal oxides during the oxidation process is dependent on alloy composition and surface treatment. Anusavice KJ et al,[4] de Melo RM et al,[5]Prettie M et al,[6]UusaloEKet al[7] have evaluated the bond strength of base metal alloys to ceramic and have reported that bond strength ranges from 35MPa-95MPa. Metal ceramic restorations have been increasingly replaced by all ceramic restorations in recent years because of their superior aesthetics, inertness and biocompatibility.[8] However, the inherent brittleness of all-ceramic systems may lead to premature failure, especially under repeated contact loading in moist environments.[9]

The failure rate is significantly higher in all ceramic when compared to metal ceramic system.[10] A key determinant for long term success of zirconia system is the bond between the ceramic and the zirconia core. In the present study, shear bond strength between a metal and porcelain in a metal ceramic system and shear bond strength between zirconia core and corresponding veneering ceramic in two different commercially available zirconia systems were evaluated. Results revealed that the Mean shear bond strength value obtained in the present study for group I Metal ceramic system was 65.5700MPa followed by group III-Zirconia veneer group (AmannGirrbach)-31.3120MPa and Group II- Zirconia veneer group (Upcera) 30.0050 MPa. Analysis of the result reveals that shear bond strength value of metal ceramic was greater (more than twice) than that of the core-veneer combination of all porcelain system, there was no significant difference in mean shear bond strength values between the two zirconia groups to their corresponding veneers.

The results of shear bond strength values in the present study in group I, are in agreement with the result of studies by Akova T et al,[11] Guess PC et al,[12]Ashkanani HM et al,[13]Joias RM et al.[14] However, the results of the present study indicate a significant difference in mean shear bond strength values between the zirconia group and metal groups. This is in contrast with the result of study by Al-Dohan et al[15] and Saito et al[16] who reported that shear bond strength values of metal ceramic group and all ceramic groups are similar. The current findings are in conformity with the study of Bu-Kyung choi et al,[17] who found out that there is significant difference between shear bond strength of metal ceramic system and zirconia core veneering system. As per International Organization for Standardization; Geneva, Switzerland 1999, ISO 9693,[18] bond strength of 25MPa was accepted as minimum for metal ceramic system. The bond strength measurement of all ceramic restoration has not been standardized. Hence, the shear bond strength value of group II i.e. 30.03MPa, and shear bond strength value of group III 31.3MPa can be expected to be clinically acceptable. In other words, shear bond strength value of zirconia system, as obtained from the result of the present study is, well above the minimum requirements for standardization values for metal ceramic system.

Guess P.C et[12] al and Ashkanani et al[19] have reported that the bond strength of zirconia-based restorations was greater than that of metal—ceramic restorations. In the present study, the shear bond strength of metal ceramic was found to be greater than the shear bond strength of zirconia-core-ceramic combination. These contradictory findings may be due to difference in testing methods, study design, and the properties of the different materials used.

SEM analysis

The fracture pattern of the veneer specimens was combined, adhesive and cohesive (i.e.) adhesive at the interface and cohesive in the veneering ceramic. These failure modes are comparable to the results of other laboratory studies.[12,15,20,21] More voids were present in zirconia specimens observed in × 250 original magnifications, while at the same magnification, lesser sized voids were present in the fracture site of metal ceramic specimens. Under × 1000 magnification, the voids in group II were larger than the voids in group III specimens. These voids might have made group II and group III specimens more vulnerable to de-bonding from core zirconia. In zirconia system water can 'catalyze' the process at surface grain boundaries and the transformation of crystal continues from layer to layer through the entire body, leading to microcrack formation, grain pullout and a decrease in strength[22]. This could be a reason for the fracture of zirconia samples.

Thermo-cycling was not done in the present study, because few of the previous studies conducted by Guess et al[12] have concluded that thermo-cycling did not affect the shear bond strength values. But in order to simulate the clinical condition, the test specimens were stored in artificial saliva for 24 hours prior to testing. As per the results of the present study, the shear bond strength values of the zirconia-core veneer combinationis more than the ISO- recommended[18] minimum value for the metal-ceramic combination. Thus, zirconia core- veneer combination can be used clinically with adequate strength during mastication.

Limitations

Thermocycling and long term storage in saliva and its effect on shear bond strength was not evaluated.

Conclusion

Within the limitations of this study, we can conclude that although the shear bond strength of zirconiaveneer system is comparatively less than metal ceramic system, the former can be used with predictable success in clinical conditions.

Conflict of interest- NIL
Source of funding- non-Funding

References

1. Akova T, Ucar Y, Tukay A, Balkaya MC, Brantley WA. Comparison of the bond strength of laser-sintered and cast base metal dental alloys to porcelain. Dent Mater 2008;24:1400-4.

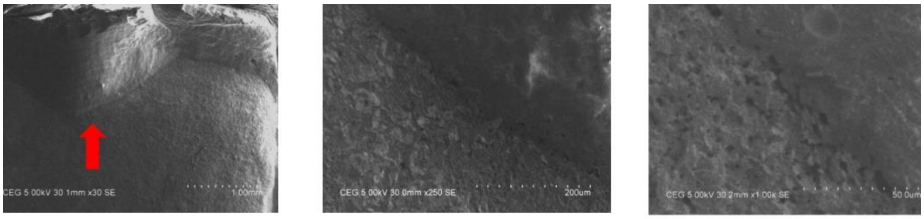
2. Al-Dohan HM, Yaman P, Dennison JB, Razzoog ME, Lang BR. Shear strength of core-veneer interface in bi-layered ceramics. J Prosthet Dent 2004;91:349-55
3. Anusavice KJ, Ringle RD, Fairhurst CW. Adherence controlling elements in ceramicmetal systems. II. Nonprecious alloys. J Dent Res 1977;56:1053-61.
4. Ashkanani HM, Raigrodski AJ, Flinn BD, Heindl H, Mancl LA. Flexural and shear strengths of ZrO2 and a high-noble alloy bonded to their corresponding porcelains. J Prosthet Dent 2008;100:274-84.
5. Ashkanani HM, Raigrodski AJ, Flinn BD, Heindl H, Mancl LA. Flexural and shear strengths of ZrO2 and a high-noble alloy bonded to their corresponding porcelains. J Prosthet Dent 2008;100:274-84.
6. Bond strength evaluation of the veneering-core Ceramics bondsMed Oral Patol Oral Cir Bucal. 2010 Nov 1;15 (6):e919-23).
7. Choi BK, Han JS, Yang JH, Lee JB, Kim SH. Shear bond strength of veneering porcelain to zirconia and metal cores J AdvProsthodont 2009;1:129-35
8. deMelo RM, Travassos AC, Neisser MP. Shear bond strengths of a ceramic system to alternative metal alloys. J Prosthet Dent 2005;93:64-9.
9. Dündar M, Ozcan M, Gökçe B, Cömlekoğlu E, Leite F, Valandro LF. Comparison of two bond strength testing methodologies for bilayered all-ceramics. Dent Mater. 2007;23:630–636.
10. Fischer J, Stawarczyk B, Trottmann A, Ha¨mmerle CH. Impact of thermal properties of veneering ceramics on the fracture load of layered Ce-TZP/A nanocomposite frameworks. Dent Mater 2009;25:326-30.
11. Guazzato M, Proos K, Sara G, Swain MV. Strength, reliability, and mode of fracture of bilayered porcelain/core ceramics. Int J Prosthodont2004;17:142-9.TomazKosmac, Strength and Reliability of Surface Treated Y-TZP Dental Ceramics, J Biomed Mater Res (ApplBiomater) 53: 304–313, 2000
12. Guazzato M, Proos K, Sara G, Swain MV. Strength, reliability, and mode of fracture of bilayered porcelain/core ceramics. Int J Prosthodont2004;17:142-9.
13. Guess PC et al Shear bond strengths between different zirconia cores and veneering ceramics and their susceptibility to thermocycling, Dental Materials. 2008 Nov;24(11):1556-67.
14. ISO 9693 Metal-ceramic bond characterization (Schwickerath crack initiation test) Geneva, Switzerland: International Organization for Standardization; 1999.
15. Joias RM, Tango RN, Junho de Araujo JE, Junho de Araujo MA, Ferreira AnzaloniSaavedraGde S, Paes-Junior TJ, *et al.* Shear bond strength of a ceramic to Co-Cr alloys. J Prosthet Dent 2008;99:54-9 .
16. Kelly JR, Denry I. Stabilized zirconia as a structural ceramic: an overview. Dent Mater 2008;24:289–298.
17. Malaka, I. G., Syarif, S., Arsyad, M. A., Baso, Y. S., & Usman, A. N. (2021). Development of women's reproductive health application as android-based learning media of adolescent knowledge. International Journal of Health & Medical Sciences, 4(2), 182-188. https://doi.org/10.31295/ijhms.v4n2.1685
18. Ozkurt Z, Kazazoglu E, Unal A. In vitro evaluation of shear bond strength of veneering ceramics to zirconia. Dent Mater J 2010;29:138-46.

19. Pretti M, Hilgert E, Bottino MA, Avelar RP. Evaluation of the shear bond strength of the union between two Co-Cr alloys and a dental ceramic. J Appl Oral Sci2004;12:280-4.
20. Rosenblum MA, Schulman A., A review of all-ceramic restorations.J Am Dent Assoc. 1997 Mar;128(3):297-307
21. Saito A, Komine F, Blatz MB, Matsumura H. A comparison of bond strength of layered veneering porcelains to zirconia and metal. J Prosthet Dent 2010;104:247—57
22. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). Health and treatment of diabetes mellitus. International Journal of Health Sciences, 5(1), i-v. https://doi.org/10.53730/ijhs.v5n1.2864
23. Tinschert J, Natt G, Mohrbotter N, Spiekermann H, Schulze KA. Lifetime of alumina- and zirconia ceramics used for crown and bridge restorations. Journal of Biomedical Materials Research Part B, Applied Biomaterials 2007;80:317–21
24. Uusalo EK, Lassila VP, Yli-Urpo AU. Bonding of dental porcelain to ceramic-metal alloys. J Prosthet Dent 1987;57:26-9.
25. Widana, I. K., Sumetri, N. W., & Sutapa, I. K. (2018). Effect of improvement on work attitudes and work environment on decreasing occupational pain. International Journal of Life Sciences, 2(3), 86–97. https://doi.org/10.29332/ijls.v2n3.209

Appendix

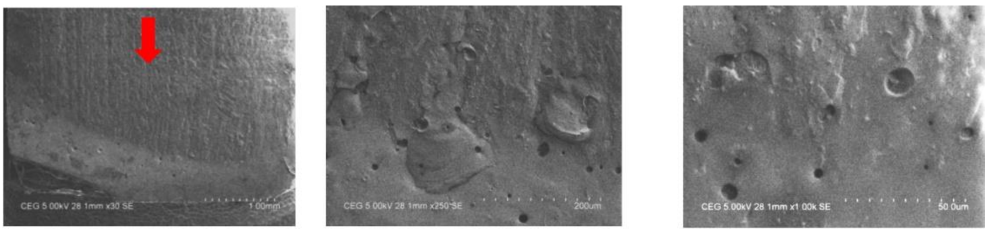
Figure 1. CAD CAM of zirconia blocks

Figure 2. All specimens in their standard dimension



A B C

Figure 3. SEM image of base metal alloy-veneer group (Group I). (A)The arrow indicates the direction of load. The loaded side demonstrates cohesive failure within the veneering porcelain (original magnification × 30), (B) Interface of the veneering porcelain and the metal core (original magnification × 250), (C) High magnification SEM image exhibited an opaque layer and an oxide layer (original magnification × 1000)



A B C

Figure 4. SEM image of zirconia-veneer group (Group II & III) (A)The arrow indicates the direction of load. The loaded side demonstrates cohesive failure within the veneering porcelain (original magnification × 30), (B) shows many pores within veneering `porcelain (arrow), where fracture originated. (C) High magnification SEM image exhibited a very thin layer of porcelain covering zirconia grains (original magnification × 1000)

Table 1

This table shows the minimum and maximum values of the three tested groups and the mean and standard deviation values

	N	Mean (MPa)	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum MPa	Maximum (MPa)
					Lower Bound	Upper Bound		
Group I-Metal core-ceramic	10	65.570000	4.3253491	1.3677955	62.475832	68.664168	57.4500	71.8500
Group II-Zirconia core - ceramic (Upcera)	10	30.005000	4.7903288	1.5148350	26.578205	33.431795	22.5700	35.7600
Group III-Zirconia core - ceramic (Amanngirrbach)	10	31.312000	6.0145930	1.9019813	27.009419	35.614581	23.7100	40.1900

Table 2
ANOVA

	Sum of Squares	Df	Mean Square	F	p Value
Between Groups	8133.960	2	4066.980	156.762	0.000*
Within Groups	700.481	27	25.944		
Total	8834.441	29			
*p Value Significant at the level <0.05					

Table 3
Post HOC Tukeys test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	p Value	95% Confidence Interval	
					Lower Bound	Upper Bound
Metal core – ceramic	Zirconia core - ceramic (Upcera)	35.5650000*	2.2778824	0.000*	29.917178	41.212822
	Zirconia core - ceramic (amanngirrbach)	34.2580000*	2.2778824	0.000*	28.610178	39.905822
Zirconia core - ceramic (Upcera)	Metal core – ceramic	-35.5650000*	2.2778824	0.000*	-41.212822	-29.917178
	Zirconia core - ceramic (amanngirrbach)	-1.3070000	2.2778824	.835	-6.954822	4.340822
Zirconia core - ceramic (amanngirrbach)	Metal core – ceramic	-34.2580000*	2.2778824	0.000*	-39.905822	-28.610178
	Zirconia core - ceramic (Upcera)	1.3070000	2.2778824	.835	-4.340822	6.954822
*p Value Significant at the level <0.05						