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Research Article

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Comparative Evaluation of Shear Bond Strength between Porcelain and Commercially Available Cobalt Chromium Alloys – An In-Vitro Study

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Abstract: The aim of the study was to compare the shear bond strength of porcelain to three commercially available cobalt-chromium alloys. There were studies evaluating shear bond strength between porcelain and nickel chromium alloys and hence this study was conducted to evaluate shear bond between cobalt-chromium alloys. Our objective is to evaluate the pattern of bonding of porcelain to cobalt-chromium alloys and also to compare the shear bond strength of porcelain with cobalt-chromium alloys. A total of 30 samples, each 10 samples of Castco, Wironit, and Girobond NBS cobalt-chromium alloy were subjected to porcelain (Vita V60 i-Line) firing. After the porcelain firing, all the samples were then tested for the shear bond strength by using the Instron (Universal testing machine). After testing the samples, the data were tabulated and analysed using one way ANOVA test ($p<0.05$) using the SPSS software. The mean shear bond strength of Wironit alloy on porcelain when evaluated was 9.9 with standard deviation of 1.92. The mean shear bond strength of Castco alloy on porcelain was 11.9 with standard deviation of 3.5. The mean shear bond strength of Girobond NBS alloy on porcelain was 9.9 with standard deviation of 3.1. From the above results, it was concluded that the Castco alloy achieved significantly higher bond strength compared to the other two. Given the sample size, we conclude that Castco has superior bond strength over Wironit and Girobond NBS. In future, research relating to the tensile and compressive bond strength between porcelain and cobalt-chromium alloy can be considered.

Keywords: shear bond, ceramic, cobalt-chromium alloy, porcelain, ceramo-metal restoration

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1. INTRODUCTION

Metal ceramic restorations are widely used due to the aesthetic demand. Advanced research on newer materials and techniques has been carried out extensively to improve the metal-ceramic restorations.[1] The restoration consists of a metal substructure that is veneered with a layer of fused porcelain to mimic the appearance of a natural tooth. Because of their excellent biocompatibility and superior aesthetic qualities, porcelain fused to metal crowns and bridges are commonly applied in fixed prosthodontics.[2] Metal to ceramic bonding is of utmost importance in the success of such restorations. Porcelain material veneered to the metal coping has the potential to fracture due to factors such as impact and fatigue load, occlusal forces, incompatible coefficient of thermal expansion (CTE) between the porcelain and metal substructure, use of metal with low-elastic modulus, seating force during trial insertion, cementation, improper design, micro defects within the material, and trauma.[3] Nickel-chromium (Ni-Cr) alloys were used to fabricate the dental crowns, bridges, and partial denture frameworks since nickel was economically cheaper than gold. However, certain reactions were seen with the use (Ni-Cr) alloys. The most common adverse reaction was of allergic response and the metal which was responsible for this reaction was Nickel in the alloy. Nickel in the alloy was found to be positive animal carcinogen according to the toxicity data. In some reported cases of allergic reactions, changes in the systemic metabolic process with conjunctivitis, dermatitis, bronchitis have been seen. Therefore, cobalt-chromium (Co-Cr) alloys were developed to nullify the effects of toxic effects of alloys containing nickel. The absence of nickel in the composition of these Co-Cr alloys, made them to be the choice of material for the fabrication of crowns and bridges for patients sensitive to nickel and hence Co-Cr alloys are replacing Ni-Cr alloys due to the nature of being more biocompatible and also due to the decreased rate of metal ion release.[4] In light of the above, the aim of the present study was to compare the shear bond strength of porcelain to three commercially available Co-Cr alloys. The objectives of the study was, to determine the shear bond strength of ceramic (Vita V60 i-Line) with three different commercially available Co-Cr alloys (Castco, Wironit, Girobond NBS).

2. MATERIALS AND METHODS

The present *in-vitro* study was conducted to evaluate the shear bond strength of porcelain to Co-Cr alloys for porcelain fused metal restoration. It was an *in-vitro* study conducted with three different commercially available Co-Cr alloys. This study was conducted at the Department of Prosthodontics Crown and Bridge, Vinayaka Mission's Sankarachariyar Dental College, Salem. The following materials, equipment, instruments and methodology were employed:

- Co-Cr group of base metal alloys (Wironit, Castco, Girobond NBS)
- Opaque and Dentin ceramic (Vita V60 i-Line)
- Bego crown wax
- Bellasun Investment material
- Muffle Furnace
- Casting Furnace
- Rayfaster
- Sandblaster
- Trimming and polishing bur for metal
- Vita Porcelain oven
- Light microscope
- Instron (Universal testing machine)

2.1 *Preparation of metal dies[1]*

The metal specimens were obtained using the lost-wax casting method, with a metal mold consisting of 2 independent pieces. Part A, a ring (15 mm in diameter and 5 mm high) with a central hole (4 mm in diameter), and with a base of 5 mm in diameter and 1 mm high. Part B consisted of a piston used to remove the wax pattern from Part A (Fig 1).

2.2 *Preparation of wax pattern[1]*

Fabrication of wax pattern samples for preparing alloy specimens was made by melting casting wax to the milled portion of the metal die. Blue crown wax was used for the preparation of wax specimens as per the dimensions of a metal die. The molten wax was filled into the space created in the metal die and the wax was allowed to cool to room temperature. The wax specimens were removed from the block without any damage or distortion. A total of 30 wax patterns were made for fabrication of 30 Co-Cr alloy samples.

2.3 *Investing procedure*

Prior to investing, patterns were thoroughly cleaned with debubblizer. Phosphate bonded investment Bellasun was used for investing. The investing material was mixed according to the manufacturer's instructions and poured into the investing ring. All precautions have been taken to see that there were no air bubbles induced to the mold.

2.4 *Casting of alloy samples[2]*

The investment was allowed to set for three hours before keeping for the burnout. The investment rings were placed in burnout furnaces for wax elimination. Once the burnout temperature reaches 950°C and after confirming that there was a total elimination of wax, the ring was transferred to the induction casting machine. The casting was done in groups of 5 wax patterns in one casting ring. Thus a total of 5x6=30 castings were made for the requirement of the study. After completing bench cooling, the casting ring was divested and sandblasted using 110µ Aluminium oxide to remove the remnants of investment material. Sprues were cut off and specimens were finished using carborundum discs under high-speed lathe instrument. All the specimen bonding surfaces were smoothed with silicon carbide papers.

2.5 *Preparation of porcelain samples[2,3]*

Same metal die of a base diameter of 5 mm and height 1 mm was used for the fabrication of porcelain samples. Portions of body porcelain-Vita V60 i-LINE mixed with build-up liquid medium and condensed in the milled area of metal die with 1 mm thickness in the upper portion of the metal die. Condensed material was placed on porcelain mat for firing and kept it in a porcelain oven and firing was done according to the manufacturer. After firing the specimens were allowed to cool to room temperature. A total number of 30 samples of porcelain were made. (Figure 2)

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2.6 *Testing procedure for shear bond strength samples*[1,3]

Shear bond strength was tested with a universal testing machine-Instron 3385 with a 20-kN load, at 1 mm/min crosshead speed using a chisel-shaped rod, which is specially designed to deliver the shearing force. The chisel end of the rod was positioned at the interface between the alloy surface and ceramic. The samples were secured tightly in place to ensure that the cylinder was always at 90° to the vertical plane. The samples were loaded until they were fractured. The forces were recorded in Newton later these values are converted into Mega Pascal by dividing the force by the bonding surface area. After the testing in the universal testing machine all the samples were then viewed under light microscope to evaluate the surface of the porcelain (Fig 3).

3. STATISTICAL ANALYSIS

The data obtained were tabulated using Microsoft Excel (Microsoft, USA) and SPSS (SPSS for Windows 10.0.5, SPSS Software Corp., and Munich, Germany) software. The mean and standard deviation was obtained for each test group and the results were statistically analysed using one way ANOVA using the SPSS software.

4. RESULTS

In this study, the evaluation of the shear bond strength of porcelain with 3 commercially available Co-Cr alloys was made. The following conclusions were drawn within the limitations of the study (Table 1 and 2). Bar diagram shows the comparison of all 3 Co-Cr alloys mean value (Figure 4)

- The shear bond strength of Wironit alloy on ceramic when evaluated the mean value was 9.9 and standard deviation value was 1.92
- The shear bond strength of Castco alloy on ceramic when evaluated the mean value was 11.9 and standard deviation value was 3.5
- The shear bond strength of Girobond NBS alloy on ceramic when evaluated the mean value was 9.9 and standard deviation value was 3.1

Table 1: Shows the compressive shear load values of Wiron IT alloy, Castco alloy and Girobond NBS alloy after using Instron universal testing machine.

	Wironit	Castco	Girobond NBS
Sample No	Compressive Shear Load(N/m^2)	Compressive Shear Load (N/m^2)	Compressive Shear Load(N/m^2)
1	8.56	7.4	10.088
2	12.858	14.532	12.084
3	8.657	16.368	7.08
4	11.567	14.541	9.247
5	8.588	9.434	11.08
6	7.3	11.043	9.47
7	8.394	17.248	13.8
8	9.434	8.886	6.703
9	12.092	9.26	14.34
10	11.404	9.985	5.223
Standard Deviation	1.92	3.5	3.1
Mean	9.9	11.9	9.9
Std. Error	0.60	1.1	0.95

Table 2: Statistical Analysis (ANOVA Summary)

ANOVA Summary				
Degrees of Freedom DF	Sum of Squares SS	Mean Square MS	F-Stat	P-Value
2	25.9089	12.9545	1.562	0.2281

($p<0.05$) statistically not significant

Fig 1: Metal Die

Fig 2: Samples after Opaque and dentin ceramic application

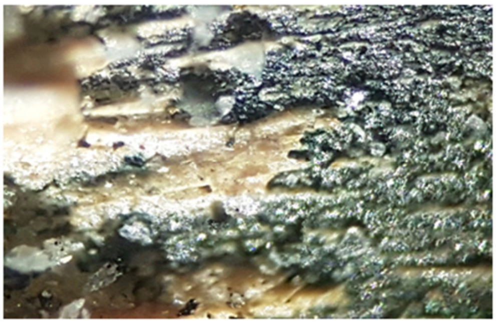

Fig 3. Microscopic view after compressive shear Load

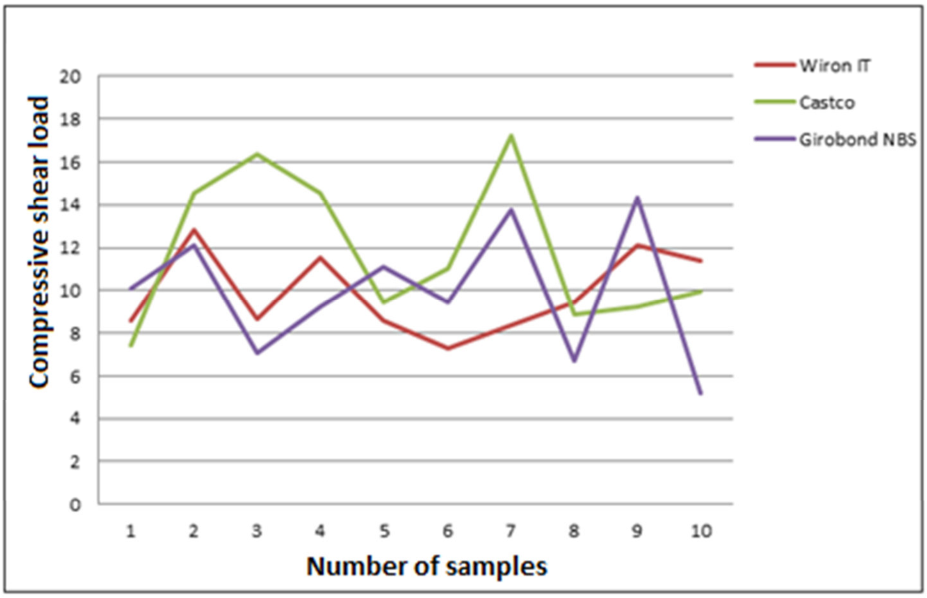

Fig 4: Bar diagram shows the comparison of all 3 Co-Cr alloys mean value

5. DISCUSSION

The success of metal-ceramic restoration depends on the reliable bond between the veneered ceramic and alloy. The longevity mainly depends on the oxide layer formed. If the oxide layer is present, it would be eliminated during ceramic sintering, which results in poor bonding. Whereas if the oxide layer is very thick, then the cohesive strength will be weak. The formation of metal oxides during the oxidation process is dependent on alloy composition and surface treatment[5,6]. Studies have shown that adequate bond strength is obtained between Co-Cr alloy and veneering porcelain[7,8]. The use of Ni-Cr alloy was discouraged due to an allergic reaction of the presence of Ni[8]. Due to that, Co-Cr alloy became popular as it is more biocompatible. The Co-Cr alloys have favourable physical and mechanical properties[9]. Adhesion between metal and ceramic is essential for the clinical success of metal-ceramic restorations, because a very complex stress situation occurs in the interface, with the tendency for development of cracks in their zone. Several tests are capable of evaluating the metal-ceramic bond strength such as flexural mode, twist, shear, tension or the combination of few, all presenting advantages and disadvantages. Some authors considered that the Shear test as the adequate measures to evaluate the bond strength between 2 materials. This type of test is performed so that tension is induced directly on the interface between the studied materials.[10,11,12] Even though the International Organization for Standardization (ISO) 9693 has recommended the evaluation of bond strength between the alloy and porcelain using the 3-point bending test method, some studies evaluated the bond using the shear bond test technique. Literature shows that there was no significant difference between the results of these 2 methods[13, 14, 15]. The stress concentration at the metal-ceramic interface will be different when different tests are used. Shear stress is the dominant stress in the shear bond test and thus in the present study the shear bond strength was used to test the bond strength at the metal – ceramic interface. The dominant stress in the shear bond test is shear stress, while in the 3-point bending test, tensile stress predominates. Therefore in the present study, the shear bond strength was tested using the universal testing machine in an attempt to evaluate the bond at the metal-ceramic interface. The chemical bond is determined by the base elements existing in the dental alloy and the wetting ability of the alloy by ceramic[16]. Compression bond depends on the geometry of the metal frame and co-efficient of thermal expansion (CTE) of metal and porcelain[17]. The most crucial bond mechanism is the chemical type and an oxide layer is responsible to adhere the porcelain to metal. An oxide layer forms on the surface of most dental porcelain fused to metal (PFM) alloys when they are exposed to oxygen at high temperatures[18]. The oxide on the surface of the metal provides the bridging link for adherence of porcelain to the metal. If the oxide layer is present, it can cause the failure of bond between the metal and ceramic. The three Co-Cr materials used are Wironit, Castco, Girobond NBS and the porcelain used is Vita V60 i-Line wash opaque and body porcelain. Among the tested 3 Co-Cr materials Castco appears to have higher shear bond strength than the Girobond NBS and Wironit. It could be due to the higher wettability of porcelain and the better formation of the oxide layer due to the composition of alloy[17]. The airborne particle abrasion of bonding surfaces increases the metal surface energy improving the wettability of opaque ceramic and consequently the bond strength through micromechanical bonding. It is very important for metal ceramic systems the Coefficient of thermal expansion (CTE) of porcelain either matches or slightly lower than the metal base as a result of which no cracks are produced in the porcelain layers due to the thermal expansion mismatch stress occurring during cooling[19,20]. Fracture analysis was done under Electron microscope and the metal-ceramic interface was examined after the shear tests were carried out and fracture of ceramic was noticed. The bond strength values of the materials tested were not different.

6. LIMITATIONS OF THE STUDY

The present study had some limitations, as this was a pilot study and in future more number of test samples can be incorporated in the study design.

7. CONCLUSION

In this study, the evaluation of the shear bond strength of porcelain towards3 commercially available Co-Cr alloys the following conclusions were drawn. The shear bond strength of Wironit alloy on ceramic when evaluated the mean value was 9.9 and standard deviation value was 1.92. The shear bond strength of Castco alloy on ceramic when evaluated the mean value was 11.9 and standard deviation value was 3.5. The shear bond strength of Girobond NBS alloy on ceramic when evaluated the mean value was 9.9 and standard deviation value was 3.1. The Castco alloy achieved significantly higher bond strength compared to the other two. Given the sample size and the limited resource, a definite conclusion that Castco has superior bond strength over Wironit and Girobond NBS cannot be ruled out, but it does have a better shear bond strength than the other two materials.

8. AUTHOR CONTRIBUTION STATEMENT

Dr. Arun kumar conceptualized and gathered the data with regard to this work. Dr. Syed Ershad Ahmed and Dr. Vignesh Veerakumar analysed these data and Dr. Parithimar Kalaignan gave necessary inputs in drafting the manuscript and also towards the designing of the manuscript. All authors discussed the methodology and results and contributed to the final manuscript.

9. CONFLICT OF INTEREST

Conflict of interest declared none.

10. REFERENCES

1. Fernandes Neto AJ, Panzeri H, Neves FD, Prado RA, Mendonça G. Bond strength of three dental porcelains to Ni-Cr and Co-Cr- Ti alloys. Braz Dent J. 2006;17(1):24-8. doi: 10.1590/S0103-64402006000100006, PMID 16721460.
2. De Melo RM, Travassos AC, Neisser MP. Shear bond strengths of a ceramic system to alternative metal alloys. J Prosthet Dent. 2005;93(1):64-9. doi: 10.1016/j.prosdent.2004.10.017, PMID 15624000.
3. Pretti M, Hilgert E, Bottino MA, Avelar RP. Evaluation of the shear bond strength of the union between two CoCr-alloys and a dental ceramic. J Appl Oral Sci. 2004;12(4):280-4. doi: 10.1590/S1678-77572004000400005, PMID 20976397.
4. Singh A, Ramachandra K, Devarhubli AR. Evaluation and comparison of shear bond strength of porcelain to a beryllium-free alloy of nickel-chromium, nickel and beryllium free alloy of cobalt-chromium, and titanium: An in vitro study. J Indian Prosthodont Soc 2017;17:261-6. Doi: 10.4103/jips.jips_337_16
5. Uusalo EK, Lassila VP, Yli-Urpo AU. Bonding of dental porcelain to ceramic-metal alloys. J Prosthet Dent. 1987;57(1):26-9. doi: 10.1016/0022-3913(87)90111-9, PMID 3543308.
6. International Organization for Standardization, ISO 9693. Metal-ceramic dental restorative systems. 2nd ed; 1999e.
7. Bagby M, Marshall SJ, Marshall GW Jr. Metal ceramic compatibility: a review of the literature. J Prosthet Dent. 1990;63(1):21-5. doi: 10.1016/0022-3913(90)90259-F, PMID 2404102.
8. Ozcan M. Fracture reasons in ceramic-fused-to-metal restorations. J Oral Rehabil. 2003;30(3):265-9. doi: 10.1046/j.1365-2842.2003.01038.x, PMID 12588498.
9. Torres F, das Graças M, Melo M, Tosti A. Management of contact dermatitis due to nickel allergy: an update. Clin Cosmet Investig Dermatol. 2009 Apr 17;2:39-48. doi: 10.2147/ccid.s3693, PMID 21436967.
10. Rosenstiel SF, Land MF, Fujimoto J. Con- temporary fixed prosthodontics. 4th ed. St. Louis: Elsevier Health Sciences; 2006. p. 612-7.
11. Azer SS, Ayash GM, Johnston WM, Khalil MF, Rosenstiel SF. Effect of esthetic core shades on the final color of IPS Empress all-ceramic crowns. J Prosthet Dent. 2006;96(6):397-401. doi: 10.1016/j.prosdent.2006.09.020, PMID 17174656.
12. Papazoglou E, Brantley WA, Carr AB, Johnston WM. Porcelain adherence to high-palladium alloys. J Prosthet Dent. 1993;70(5):386-94. doi: 10.1016/0022-3913(93)90072-V.
13. Papazoglou E, A. Brantley WA, Carr AB, Johnston WM. Porcelain adherence vs force to failure for palladium–gallium alloys: a critique of metal–ceramic bond testing. Dent Mater. 1998;14(2):112-9. doi: 10.1016/S0109-5641(98)00017-7.
14. Papazoglou E, Brantley WA, Johnston WM, Carr AB. Effects of dental laboratory processing variables and in vitro testing medium on the porcelain adherence of high-palladium casting alloys. J Prosthet Dent. 1998;79(5):514-9. doi: 10.1016/S0022-3913(98)70171-4, PMID 9597603.
15. Nally JN. Chemico-Physical analysis and mechanical tests of the ceramo-metallic complex. Int Dent J. 1968;18(2):309-25. doi: 10.1016/S0022-3913(96)90244-9, PMID 4874291.
16. Mackert JR Jr, Ringle RD, Parry EE, Evans AL, Fairhurst CW. The relationship between oxide adherence and porcelain-metal bonding. J Dent Res.

1988;67(2):474-8. doi: 10.1177/00220345880670020801, PMID 11039060.

17. Daftary F, Donovan T. Effect of four pretreatment techniques on porcelain-to-metal bond strength. J Prosthet Dent. 1986;56(5):535-9. doi: 10.1016/0022-3913(86)90416-6, PMID 3534223.

18. Bezzon OL, Ribeiro RF, Rollo JM, Crosara S. Castability and resistance of ceramometal bonding in Ni-Cr and Ni-Cr-Be alloys. J Prosthet Dent. 2001; 85(3): 299-304. doi: 10.1067/mpr.2001.113779, PMID 11264939.

19. Yilmaz H, Dinçer C. Comparison of the bond compatibility of titanium and a NiCr alloy to dental porcelain. J Dent. 1999; 27(3):215-22. doi: 10.1016/S0300-5712(98)00045-1.

20. Al Amri MD, Hammad IA. Shear bond strength of two forms of opaque porcelain to the metal substructure. King Saud University Journal of Dental Sciences. Den. 2012;3(2):41-8. doi:10.1016/j.ksujds.2012.05.001.