DOI: 10.5958/2319-5886.2015.00030.2

International Journal of Medical Research & Health Sciences

www.ijmrhs.com Volume 4 Issue 1 Coden: IJMRHS Copyright @2014 ISSN: 2319-5886

Received: 5th Dec 2014 Revised: 26th Dec 2014 Accepted: 30th Dec 2014

Research article

A COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF PORCELAIN FUSED TO METAL SUBSTRUCTURE FABRICATED USING CONVENTIONAL AND CONTEMPORARY TECHNIQUES: AN IN VITRO STUDY

*Mhaske Prasad N[1], Nadgere Jyoti B[2], Ram Sabita M[3]

[1]Lecturer, Department of Prosthodontics, Rural Dental College and Hospital, Loni, Ahmednagar, Maharashtra, India

[2]Professor, [3]Dean, Professor and Head, Department of Prosthodontics MGM Dental College and Hospital, Kamothe, Navi Mumbai, Maharashtra, India

*Corresponding author Email: drprasadmhaske@gmail.com

ABSTRACT

Base metal alloys due to their low cost, are being used more often as the substructure because of their good mechanical properties, excellent metal ceramic bonding and biocompatibility. The bonding of porcelain to metal is an important point to be considered for the success of the restoration. **Aim**: To compare and evaluate the shear bond strength of porcelain fused to metal substructure fabricated using conventional and contemporary techniques. **Methods and Material**: Thirty sample discs were fabricated – 10 of cast nickel chromium alloy, 10 of cast cobalt chromium alloys and 10 of laser sintered cobalt chromium alloy. Conventionally used feldspathic porcelain was used and fired over the metal discs. These samples were placed in a specially fabricated jig, which was held in a universal testing machine. The samples were subjected to shear stress until they fractured and the readings were noted. The fractured surface of the sample was then viewed under stereomicroscope. **Results**: The mean shear bond strength was highest in group C (porcelain fused to laser sintered cobalt chromium), followed by group A (porcelain fused to cast nickel chromium) and group B (porcelain fused to cast cobalt chromium) which was the least. The level of significance was fixed at $p < 0.05$. After applying Student's Unpaired 't' test there is no significant difference in shear bond strength in group A compared with group B, highly significant in group A and group C and very highly significant in group B and group C. **Conclusions**: All the three groups showed adequate, but laser sintered cobalt chromium alloy had the highest shear bond strength to porcelain. Nickel chromium alloy fabricated by conventional casting method showed lesser values of the shear bond strength, followed by cobalt chromium alloy fabricated by conventional casting, which had the least shear bond strength.

Key words: Shear bond strength, porcelain fused to metal, laser sintered cobalt chromium, direct metal laser sintering.

INTRODUCTION

Fixed restorations can be fabricated in various materials such as, metals which include precious, semi-precious and non precious alloys, porcelain fused to metal restoration and full ceramic restorations. Full ceramic restorations with enhanced aesthetics have become very popular, but do have their limitations. Full ceramic restorations with enhanced aesthetics have become very popular, but do have their limitations. The demands for full metal restoration has decreased because of unpromising aesthetics and are advocated in fewer situations, whereas porcelain fused to metal restorations have always remained as gold standard due to their high strength and good aesthetics. For the restoration to fulfil esthetic requirements, porcelains have been fused to metal for fabrication of restorations. Porcelain fused to precious metal restorations were in demand in the late 20th century and the beginning of the 21st century as it improved the esthetics of the restoration and the yellow colour of gold resulted in a more natural appearance for the restoration[1]. Base metal alloys, due to their low cost, are being used more often as the substructure because of their good mechanical properties, excellent metal ceramic bonding and biocompatibility. The bonding of porcelain to metal is an important point to be considered for the success of the restoration[2]. Failure in the bonding between the porcelain and metal may lead to debonding of porcelain from the metal substructure and failure of the restoration. The metal substructure can be fabricated by conventional casting by lost wax technique or by contemporary techniques such as CAD – CAM processing and Laser Sintering technique[3]. Nickel chromium alloy has been a popular alloy for restoration as it has its advantages, but many have reported its allergies and hence attempts are made to fabricate the substructure with an alternative alloy such as cobalt chromium.[4] When CAD – CAM was introduced into esthetic dentistry scene few years ago, it got with it a wide range of features such as, excellent marginal fit, reduced adjustments, superior esthetics and mechanical properties and controlled materials. However the advances in rapid manufacturing technology have brought CAD – CAM benefits within reach of mainstream dentistry.[5] Traditional metal castings require a sequence of steps to fabricate a restoration. However, with introduction of Direct Metal Laser Sintering (DMLS), the prostheses have been simplified as low cost CAD – CAM frameworks can now be produced in pure, medical grade Cobalt - Chromium. The Laser sintered porcelain fused to metal restorations gives the laboratory a new opportunity to stay ahead of the competition and keeping down the cost. This study is to evaluate and compare the shear bond strength of cast base metal alloys i.e. Nickel – Chromium, Cobalt – Chromium and Laser Sintered Cobalt – Chromium alloy to dental porcelain.

METHODS AND MATERIALS

After the approval by the Institutional Ethics Committee, the comparative study was done. In total of 30 samples were fabricated to carry out the study, which conducted 10 samples each of cast nickel chromium alloy, cast cobalt chromium alloy and laser sintered cobalt chromium alloy. A circular disc of self cure clear acrylic resin (DPI RR Cold Cure, Dental Products of India) was fabricated with dimensions 10 mm in diameter and 4 mm in thickness. A putty (Express™ XT Putty Soft, 3M ESPE) impression of this disc was made to prepare a mould for fabrication of wax pattern (Crown Wax, BEGO) for preparation of sample discs. Wax patterns in the form of disc were prepared in the putty mould. 10 wax patterns were fabricated for each of Nickel Chromium (Cerabond, BEGO) and Cobalt Chromium (Wironit®, BEGO) castings and a single wax pattern was prepared to scan three dimensionally for fabricating laser sintered cobalt chromium discs. The discs to be casted were then sprued using Sprue wax (Sprue Wax, Sigmadent). Nickel chromium, cobalt chromium alloy for conventional casting, and cobalt chromium alloy for laser sintering was used. Conventional feldspathic porcelain was also included in this study. Other metal alloys such as gold, and ceramics such as Zirconia and glass ceramics were not used for this purpose.

The pattern, following the standard water powder ratio, was then invested with a ring liner used on the casting ring to allow the expansion of the final outcome. Wax burnout was carried out in a burnout furnace (Miditherm, BEGO, USA) at the temperature of 980 ^{o}C and the mould was then subjected into an induction casting machine (– Fornax, BEGO, USA) in which the molten metal was flown into the mould for fabrication of the discs. The procedure is same for the casting of Nickel Chromium and Cobalt Chromium alloys (Fig 1).

Fig 1: Steps in fabrication of samples

Whereas on the other hand the single wax pattern prepared was scanned in a three dimensional scanner (LAVA Scan, 3M ESPE) from all the aspects. This pattern was then transferred to the machine computer with all the details of its diameter and thickness.

Conventional casting method: Fresh pellets of metal alloy were taken and casting for nickel chromiumm and cobalt chromium alloy was carried out on an induction casting machine. Once the molten metal had flown into the mould completely, it was taken out of the machine and allowed to cool gradually. The investment material was removed in aluminium oxide sand microblaster (Duostar, BEGO) and the casting was retrieved. The sprues are then cut using carborandum disc and the samples were finished using metal finishing points (Metal finishing and polishing kit – Shofu Inc.). Both the Nickel chromium and Cobalt chromium discs were finished in the same way to achieve the desired dimensions.

Laser sintering method: On the other hand the data of the scanned disc was transferred to the machine computer. The software (EOSTAT 1.2) created a CAD data and transferred it to the machine for fabrication. The machine, EOS M 270 laser sintering system has a radiation heater, a focussed laser beam at the roof, a platform on the floor with metal powder on both the sides of the platform, which is adjusted by a movable piston at the level of the platform. The metal powder is of very fine particles (20 microns), is moved over the platform and spreads evenly so that the laser beam on top melts the metal locally and the powder gets fused. This procedure was repeated until the samples were fabricated. The samples were then retrieved and finished.

All the samples were microblasted for roughening the surface. After microblasting they were subjected to ceramic furnace (Vacumat 40 T, VITA Zahnfabrik, Germany) for oxidation firing. After the oxide layer was removed, the discs were cleaned in the ultrasonic cleaner and using a steam cleaner. Now the discs were ready for porcelain build up. Feldspathic porcelains (VMK 95, VITA Zahnfabrik, Germany) were used, layer of wash opaque, after mixing the powder and liquid on a glass slab, was applied with a brush over the discs and subjected to firing cycle as per the manufacturer's instructions. After that the liquid and powder opaque was mixed to apply over the disc and was fired. The dentin layer was applied using a brush; excess liquid was withdrawn by tapping with soaking paper. Both the 1st and the 2nd dentin firing followed by enamel firing were carried out according to manufacturer's instructions. A ceramic layer of thickness 2 mm and diameter 10 mm was achieved and measured using metal gauge. Anything in excess of these dimensions was trimmed off and finished with porcelain finishing points (Shofu Inc). The discs were once again cleaned in the ultrasonic cleaner and allowed to dry for application of glaze. Application of glaze (VITA AKZENT) was followed by firing. Porcelain was fired on all the samples together to standardize the procedure (fig 2).

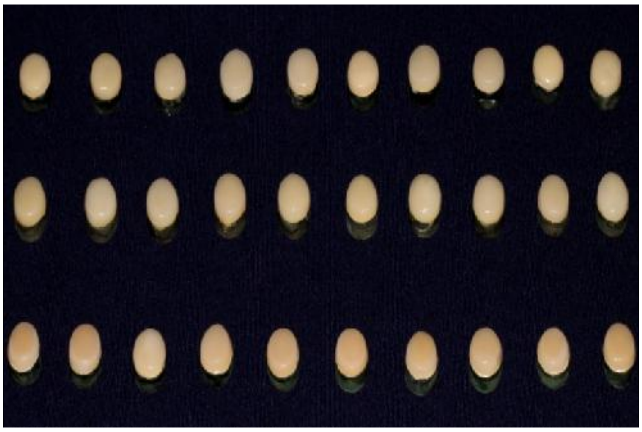

Fig 2: Samples of Group A, B and C.

The shear bond strength was measured in a Universal testing machine (Instron 3367). For this purpose a special jig was required to hold the disc. A stainless steel cylinder with a hole having internal diameter 10 mm and depth 4 mm was fabricated (Shakti Engineering and Fabricators, Navi Mumbai). At the base of the hole a screw nut assembly was attached which would enable us to move the disc up and down to get the correct interface of porcelain and metal. A special jig assembly was also fabricated with two plates. These plates had holes at both the ends, one to engage the rods for the Universal Testing Machine and another to hold the disc. The plates were positioned one over the other which had the sliding mechanism so that one plate would engage the metal part of the disc and the other plate engages the porcelain portion.

The disc was placed such that the metal porcelain interface lied exactly in between the two plates and the metal and the porcelain portion was engaged in the holes of the plates, and this entire assembly was placed in the Universal Testing Machine. The testing was done and the discs were subjected to shear load at the metal-porcelain interface with increasing load and the crosshead speed of 5 mm / sec till the disc debonded completely. The values obtained were in the units of kilogram force (KgF) and were converted into Megapascals (Mpa).

The debonded samples of cast nickel chromium, cast cobalt chromium and laser sintered cobalt chromium alloys were cleaned in an ultrasonic cleaner and were kept ready for observation under the stereomicroscope. The fractured surface of the debonded samples was observed for scoring the area of the debonded surface and determining whether the fracture was adhesive, cohesive or a mixed. The Fractographic analysis is interpreted through the Stereomicroscopic images.

This examination was done to check whether the fracture occurred was in the porcelain layer or in the interface of porcelain and metal. This determined whether the fracture was cohesive or adhesive. The fractured surface was evaluated using Adhesive Remnant Index (ARI)[4] (Fig 3,4, and 5 shows fractured surface of sample of group A, B and C respectively).

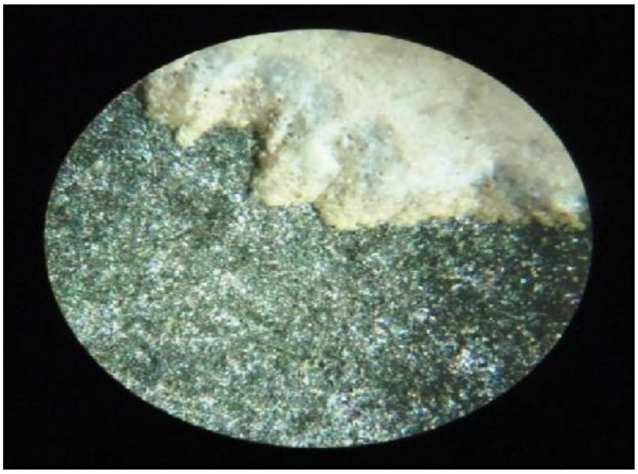

Fig 3: Stereomicroscopic image of Sample of group A

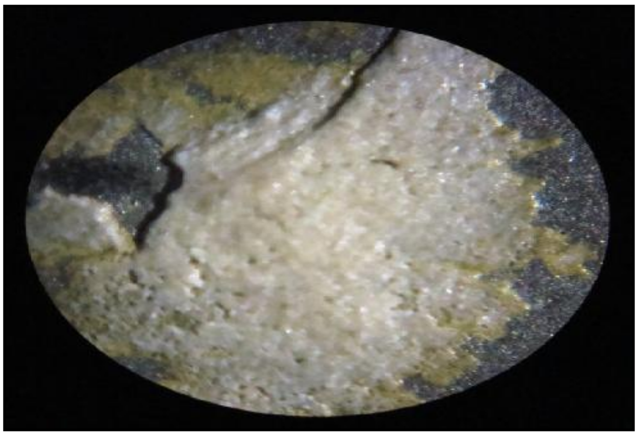

Fig 4: Stereomicroscopic image of Sample of group B

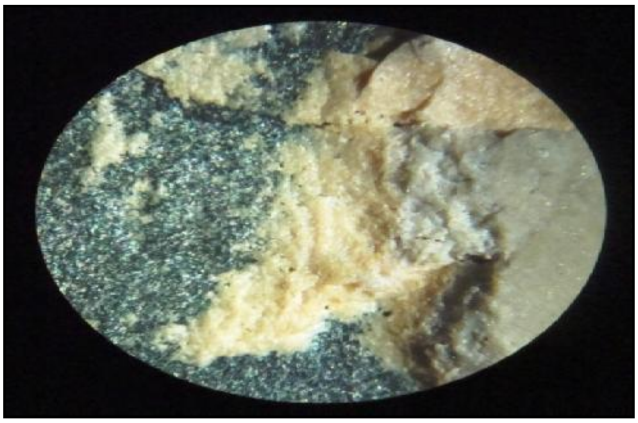

Fig 5:Stereomicroscopic image of Sample of group C

Statistical analysis: Statistical significance was determined using one - way analysis (ANOVA), followed by POST HOC test. Level of significance was $p < 0.05$. There is a highly significant difference between average values of shear bond strength when group A, B and C were compared together. After applying Student's Unpaired 't' test there is no significant difference in shear bond strength in group A compared with group B, highly significant in group A and group C and very highly significant in group B and group C.

RESULTS

The porcelain to metal shear bond strength of each sample was calculated from the load applied on a Universal testing Machine with a crosshead speed of 5 mm/ Sec. While the mean shear bond strength was higher in laser sintered cobalt chromium samples, the bond strength was significantly different ($p < 0.05$) from that of cast nickel chromium and cast cobalt chromium. The shear bond strength of cast nickel chromium (23.88 Mpa) was less as compared to laser sintered cobalt chromium (34.56 Mpa) and that of cast cobalt chromium (23.70 Mpa) was the least.

Table 1: Shear bond strength of samples of Group A in Megapascals (Mpa)

Samples	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
	19.64	17.84	29.83	18.62	35.99	18.78	24.35	26.21	29.34	18.22
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	13.80	30.12	26.67	16.74	26.19	29.69	18.65	26.05	24.59	24.56
Samples	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	47.83	48.62	28.97	30.43	25.86	37.83	34.67	32.14	28.53	30.67

Table 2: Comparison of shear bond strength between the three groups with One- way ANOVA

Samples	shear bond strength	Df	F Value	p value
Group A	23.88 ± 6.3	2.00	8.73	0.012*
Group B	23.70 ± 5.49			
Group C	34.56 ± 7.93			

Data presented as Mean ±SD, *p value < 0.05, F= Degree of Freedom

Table 3: Comparison of shear bond strength within three groups by POST HOC test

Samples	Student's 't' test value and 'p' Value with significance
Group A vs Group B	$t = 0.03$, $p > 0.05^{@}$
Group A vs Group C	$t = 3.35$, $p < 0.01$*, highly significant
Group B vs Group C	$t = 4.32$, $p < 0.001$**

[@]not significant, *highly significant, ** extreme highly significant

DISCUSSION

Many methods have been proposed to quantify such as adhesion, but none is completely exempt from errors, due to the complexity of the porcelain - metal bonding[5, 6,7]. Metal- porcelain restorations for clinical use contain thermal stresses upon which the load stresses are superimposed. For the majority of bond experiments described in the literature, stress concentration is present at the site near the load application shear tests[8].

This study was carried out first to evaluate the porcelain fused to metal bond strength of conventionally used feldspathic porcelain to cast Nickel Chromium alloy, cast Cobalt Chromium alloy and newly introduced direct metal laser sintered Chrome cobalt alloy and then to compare them. Conventionally used Ni-Cr alloy was used along with Co-Cr alloy for fabrication of the substructures. The Ni-Cr alloy is known to cause allergy and hypersensitivity reactions as found out in earlier studies. Co-Cr alloy has less bonding with the porcelain as suggested by Joias et al[9]. These alloys were fabricated using traditional lost wax casting procedure. The alloy used in the third group was laser Sintered Co-Cr alloy, which known to be medical grade alloy produced from fine metal powder of approx 20 µm in size and thereby promising 99 % density of the resultant product. Conventional used feldspathic porcelains- VITA VMK 95 was selected for layering as it is the most widely used veneering porcelain in combination with metals. Porcelain build up over these samples of the group A and B was done in a conventional method, except for group C where, wash opaque of Cerambond was used as it bonds the porcelain well with laser sintered Co-Cr alloys. A pull type of test was carried out to fracture these samples and readings were noted.

The test carried out in this study showed a significant difference in the shear bond strengths in between the three groups. The highest load required to fracture the samples was for group C, i.e., laser sintered Co-Cr, followed by cast Ni-Cr – group A and cast Co-Cr – group B. Akova[10] and associates carried out a similar study, but found out no significant difference in the bond strength of cast Ni-Cr, cast Co-Cr and laser sintered Co-Cr. They found out that all metal ceramic specimens of cast Ni-Cr and cast Co-Cr alloys exhibited a mixed mode of cohesive and adhesive failure, whereas five samples of laser sintered Co-Cr alloy exhibited a mixed failure and five samples exhibited adhesive failure in the porcelain. Cohesive failure within the porcelain is the most desirable bond failure mode[5], indicating a strong bond between the oxide layer and both the metal and ceramic. This study shows that laser-sintering the Co–Cr alloy powder to form the substructure for a metal–ceramic restoration, rather than using conventional dental laboratory casting, does not significantly degrade the metal–ceramic bond strength. One limitation of this study may be the sample size of ten for the specimen groups, and only one base metal alloy was compared with casting and laser sintering.

O'Brien[11] in 1977 classified porcelain-metal bond failures according to various interfaces and concluded that the cohesive failure within the porcelain represented a proper porcelain to metal bond. Sced and McLean[12] considered the possibility that the oxide layer formed at the interface between the materials may impair adhesion because it decreases the coefficient of thermal contraction of the porcelain. Mackert et al[13] found a positive correlation between the thickness of the oxide layer formed and the adhesion of the porcelain to the metal.

Hegedus et al[14] performed a detailed microstructural investigation to compare the reaction layer developed among 3 different brands of dental porcelains and a Ni-Cr alloy (Wiron) under different firing conditions. Evaluations of the fit of crowns made with this technique are essential before being recommended for porcelain fused to metal restorations. It should be noted that preparation of laser-sintered idealized restorations from Ti-6Al-4V have also been reported. This group noted that improvements in the processing parameters are needed to yield clinically acceptable fit of restorations prepared from the laser-sintered titanium alloy.

CONCLUSION

A total of thirty porcelain fused to metal discs were fabricated for testing the shear bond strength at the metal ceramic interface. Within the limitations of the study the following conclusions were drawn:

- Porcelain fused to laser sintered cobalt chromium alloy had the highest shear bond strength.
- The shear bond strength of porcelain fused to nickel chromium alloy was better than that of cobalt chromium alloy fabricated by conventional method but was less than that with laser sintered cobalt chromium alloy.
- The shear bond strength of porcelain fused to cobalt chromium fabricated by conventional casting showed the least among the three groups.

Limitations of the study: This study limits the evaluation of some other properties such as compressive strength and colour stability. The sample size is small and so a larger sample size can be taken into consideration for more significant results. There are several other studies are that are required for assessment of properties such as marginal fit and adaptation.

Acknowledgements: My sincere thanks to Dr. Dinesh Jain, Neerav Jain and team of Dental Ceramists (I) Pvt Ltd**.** for extending the laboratory support. I am very thankful to Mr. Hemant Pawar, for helping me with the statistical analysis.

Conflict of interest: Nil

REFERENCES

1. Woolson AH. Restorations made of Porcelains baked on Gold. J Prosthet Dent 1955;5(6):65
2. Renato M J, Rubens NT, Jose EA, Maria A J, Guilherme de Siqueira, Estevao T K, Shear bond strength of a ceramic to Co-Cr alloys: J Prosthet Dent 2008;99:54-59
3. Anders Örtorp, David Jönsson, Alaa Mouhsen, Per Vult von Steayern, The fit of cobalt–chromium three-unit fixed dental prostheses fabricated with four different techniques: A comparative in vitro study. Dent Mater 2011; 27:356–63
4. Jon Artun, Sven Burgland. Clinical trials with crystal growth conditioning as an alternative to acid etch enamel pre-treatment. Am J Orthod 1984;85(4):333-40
5. Lubovich P, Goodkind RJ. Bond strength studies of precious, semiprecious, and non-precious ceramic-metal alloys with two porcelains. J Prosthet Dent 1977; 37:288-99
6. Anusavice KJ, Dehoff PH, Fairhurst CW. Comparative evaluation of ceramic-metal bond tests using finite element stress analysis. J Dent Res 1980; 59:608-13
7. Chong MP, Beech DR. A simple shear test to evaluate the bond strength of ceramic fused to metal. Aust Dent J 1980; 25:357-61
8. Lenz J, Kessel S. Thermal stresses in metal-ceramic specimens for the ISO crack initiation test (three-point flexure bond test). Dent Mater 1998; 14:277-80
9. Renato Morales Joias, Rubens Nisie Tango, Jose Eduardo Junho de Araujo, Maria Amelia Junho de Araujo, Guilherme de Siqueira Ferreira Anzaloni Saavedra, Tarcisio Jose de Arruda Paes- Junior, Estevao Tomomitsu Kimpara.

Shear bond strength of ceramic to Co – Cr alloy. J Prosthet Dent 2008; 99:54-59

10. Tolga Akova, Yurdanur Ucar, Alper Tukay, Mehmet Cudi Balkaya, William A. Brantley. Comparison of the bond strength of laser-sintered and cast base metal dental alloys to porcelain. Dent Mater 2008; 24:1400-04
11. O'Brien, W. J.: Dental porcelains. Dental Materials Review. Ann Arbor, 1977, University of Michigan Press, pp 123-35
12. Sced IR, McLean JW. The strength of metal-ceramic bonds with base metals containing chromium. A preliminary report. Br Dent J 1972; 132: 232-34
13. Mackert JR Jr, Ringle RD, Parry EE, Evans AL, Fairhurst CW. The relationship between oxide adherence and porcelain-metal bonding. J Dent Res 1988; 67:474-78
14. Hegedus C, Daroczi L, Kokenyesi V, Beke DL. Comparative microstructural study of the diffusion zone between Ni-Cr alloy and different dental ceramics. J Dent Res 2002; 81:334-7