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Original Article

Comparative evaluation of shear bond strength between titanium-ceramic and cobalt-chromium-ceramic: An *in vitro* study

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Abstract

Aim: The aim of this study was to evaluate and compare the shear bond strength between ceramic layered over titanium and ceramic layered over cobalt-chromium alloy, which are used in the fabrication of screw-retained implant prosthesis.

Settings and Design: *In-vitro* – Comparative study.

Materials and Method: A total of 40 samples (20 samples of Titanium in Group 1 and 20 samples of Cobalt-Chromium in Group 2) were fabricated. For all the samples bonding agent was applied on to the sand blasted surface and firing was done at a temperature of 980° C. A layer of opaque was applied using a brush and placed back in the furnace at a temperature of 910° C. Then ceramic was layered on to the surface with putty index as guide and firing was done in the ceramic furnace up to a temperature of 880° C followed by glazing. Shear bond strength was measured using a Universal Testing Machine.

Statistical Analyses Used: One sample *t*-test and paired sample *t*-test.

Results: Descriptive statistics were done to calculate mean differences between groups and samples. The mean bond strength of titanium- ceramic samples was more than those of cobalt-chromium-ceramic samples. Inferential statistics used in the study were one sample *t*-test for intra-group comparison and paired sample *t*-test for inter group comparison which showed no statistically significant difference between the two metal types (P value = 0.163).

Conclusion: The shear bond strength of ceramic veneered over titanium meets the ISO requirements of minimum shear bond strength between metal-ceramic systems and has achieved the clinically acceptable values. The use of titanium super structure over titanium implants reduces the adverse effects and avoids undesirable effects.

Keywords: Cobalt-chromium, porcelain, shear bond strength, titanium

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Submitted: 06-Mar-2021, **Revised:** 03-Jun-2021, **Accepted:** 15-Jun-2021, **Published:** 10-Aug-2021

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/jips.jips_81_21

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How to cite this article: Vaska KR, Nakka C, Reddy KM, Chintalapudi SK. Comparative evaluation of shear bond strength between titanium-ceramic and cobalt-chromium-ceramic: An *in vitro* study. J Indian Prosthodont Soc 2021;21:276-80.

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INTRODUCTION

The use of metal ceramic restorations began in late 1950s allowing the development of prosthetic rehabilitation with better cosmetic results. However, the actual mechanism of adhesion of ceramic to metal is complex and is not fully understood mostly due to differences in thermal expansion and formation of oxide layer on surface of dental metal alloys. Several metal alloys have been introduced to the fabrication of implant superstructures covered with ceramic. Two among them are titanium and cobalt-chromium (Co-Cr).[1] Limited literature is available to evaluate the bond strength between titanium and ceramic and also the comparison between the bond strength of ceramic to titanium and Co-Cr.

Titanium due to its good biocompatibility, excellent biological, and mechanical properties is an ideal material for use in the human body and is being used in many fields of dentistry as well. Several transosseous and endo-osseous implantations use this material. Long-term and clinical observations have established the fact that titanium is noble and does not corrode in human tissues. Although, galvanic coupling of implant to several other metallic restorations may induce corrosion. This phenomenon is termed as galvanic corrosion or dissimilar corrosion. According to Geis-Gerstorfer *et al*.,[2] galvanic corrosion of dental materials causes: (1) dissolution of alloys and (2) destruction of underlying bone. Therefore, coupling remains a great concern for metallic superstructure covering the implant body.[3] Co-Cr alloy is also in use for fabrication of implant-supported prosthesis. It is a material of choice due to its biocompatibility and low cost features. Apart from computer-aided design/computer-aided manufacturing techniques, Co-Cr prosthesis can also be obtained through conventional casting methods, as base metal alloys have higher melting points and are more susceptible to oxidation during casting.[4]

However, these two alloys have limitations such as high melting point, high chemical reactivity, and weak bond strength with ceramic during high casting temperatures.[5]

Considering the above benefits and drawbacks associated with the two alloy combinations, this study attempted to explore the better combination among the both, in terms of shear bond strength (SBS) when ceramic is layered, to be used for fabrication of screw-retained implant prosthesis in regular clinical practice. The null hypothesis was formulated as: there is no difference in the SBS of ceramic-layered over titanium and ceramic-layered over Co-Cr alloy. The alternative hypothesis was formulated as: the SBS of ceramic layered over titanium will be higher than that of ceramic layered over Co-Cr alloy.

MATERIALS AND METHODS

Before the start of the study, permission to conduct the study and ethical clearance was taken from Institutional Ethics Committee, Sri Sai Dental College and Research Institute, Srikakulam. A total of forty samples (20 samples of titanium in Group 1 and 20 samples of Co-Cr in Group 2) were fabricated. For titanium, commercially pure titanium (White peaks, Germany) and for Co-Cr, NPX-III alloy (Nobilium, U.S.A) were selected. These alloy brands were selected due to their biocompatibility, long-term usage, and reliable processing methods.

Die fabrication

An Electric Discharge Machining (Agicut, Switzerland) was used to fabricate desired samples with dimensions 2 mm × 2 mm × 10 mm. A brass rod of 5 mm in diameter and 15 mm in length was used for this [Figures 1 and 2].

A silicone index of the die was prepared by embedding the machined die in putty poly-vinyl silicone impression material (Aquasil soft putty, Dentsply). Wax duplicates were prepared using Inlay wax (Hindustan wax). For this, the inlay wax was melted and poured in the putty pattern to obtain a wax pattern of required dimensions. The same procedure was followed, and all the twenty samples were prepared to desired dimensions. The Co-Cr samples were fabricated using conventional casting procedure [Figure 3].

Once duplication was done, all the samples were verified for any casting defects and only those that were desired were selected for further experimentation. Formation of an oxidation layer was controlled in vacuum firing of ceramic furnace. Each sample's surface was sand blasted before ceramic layering with 110 μm aluminum oxide powder at a 45° angle and 20 cm distance from sample

Figure 1: Brass die 2 mm × 2 mm × 10 mm

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at 2 bar pressure. This was placed in an ultrasonic water bath (Sky-men) for 5 min. To this sand blasted surface, bonding agent (Duceram) was applied, and firing was done at a temperature of 980°C for 2–3 min using ceramic furnace (Programatt 300, Ivoclar). After completion of specified holding period, a layer of opaque (GC for titanium, Duceram for co-cr) was applied on to the surface of the sample using a brush and placed back in the furnace at a temperature of 910°C for 4 min. Subsequently, layering of ceramic on to the surface with putty index as guide was done followed by firing in the ceramic furnace. Finally, glaze (GC for titanium, Duceram for co-cr) was applied and glazing was done. Following the same procedure, all the twenty samples of Co-Cr alloys were layered with ceramic up to a height of 2 mm (Technique adopted from Joias *et al*.[6]). SBS was measured using a Universal Testing Machine [Figure 4].

Shear bond test

In the present study, the samples were tested under universal testing machine for shear bond test at a crosshead speed of 1 mm/min. After ceramic layering, the SBS of each specimen was measured. The ultimate load (N) of each specimen was recorded. The SBS was calculated using the formula: SBS (MPa) = load (N)/area (mm^2). ISO standardization was used to interpret the shear bond test results. As per the ISO standardization, a minimum value of 25 MPa is required for metal ceramic restoration.[7] The samples were further evaluated under scanning electron microscope (SEM) to evaluate the mode of fracture. The fractured surfaces were visually examined using an optical microscope at a ×30 magnification (SMZ1000, Nikon, Tokyo, Japan) to evaluate the failure mode of specimens.

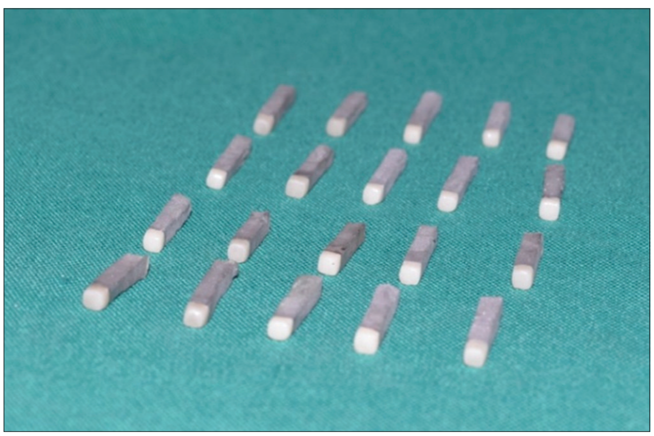

Figure 2: Samples

Figure 4: Scanning electron microscope image of cobalt-chromium ceramic specimen

RESULTS

The objective of the study was to compare the SBS between titanium–ceramic and Co-Cr-ceramic. Statistical analysis for the present study was done SPSS Version 21.0 software (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA: IBM Corp.). Descriptive statistics were done to calculate mean differences between groups and samples [Table 1]. The mean bond strength

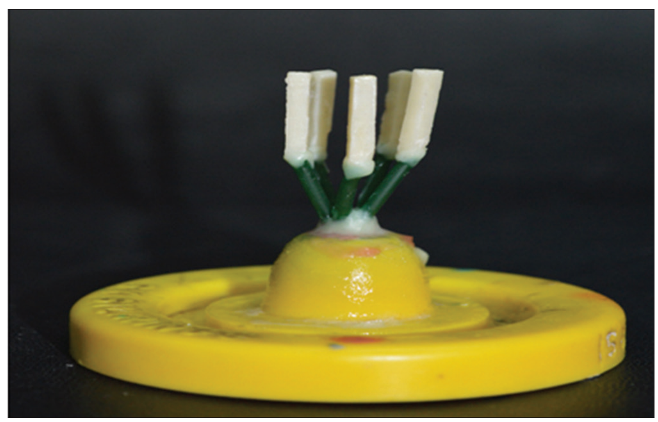

Figure 3: Wax patterns for cobalt chromium sample fabrication

Figure 5: Universal testing machine

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of titanium–ceramic samples was more than those of Co-Cr-ceramic samples. Inferential statistics used in the study were one sample *t*-test for intragroup comparison and paired sample *t*-test for intergroup comparison [Tables 2 and 3] which showed no statistically significant difference between the two metal types ($P = 0.163$). SEM images revealed that most of the samples showed a mixed failure, which include cohesive failure and adhesive failure in both Co-Cr ceramic and titanium-ceramic samples [Figures 5 and 6].

DISCUSSION

The metallic titanium dental implant/prosthesis used in dentistry derives their biocompatibility from their alloying elements responsible for the formation of continuous stable TiO_2 passive film on its surface. Corrosion of this prosthesis occurs when oral conditions are unfavorable such as using them with inappropriate metal combination which leads to galvanism and corrosion, thereby causing undesirable effects.[5] Hence, the use of dissimilar metal prosthesis with low level corrosion resistance alloys is not recommended. Literature also proposed a better clinical outcome of titanium auxiliary/superstructure over titanium implants.

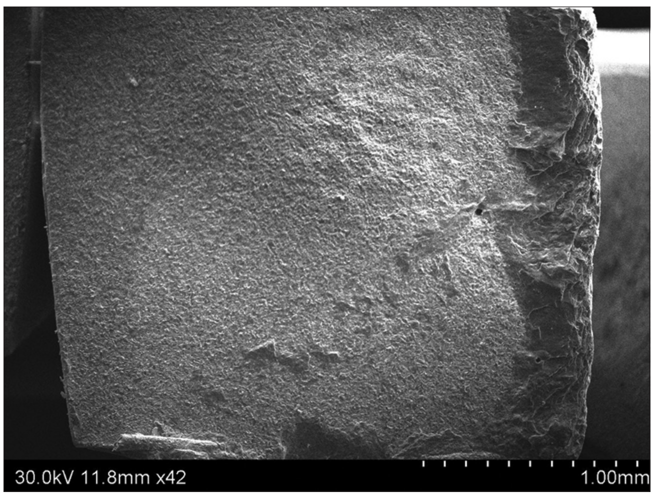

Figure 6: Scanning electron microscope image of Ti-ceramic specimen

Table 1: Mean values of samples from two groups

Metal types	*n*	Minimum	Maximum	Mean	SD
Co-Cr	20	6.65	51.38	23.9125	10.5120
Titanium	20	12.20	72.09	29.7515	14.7082

SD: Standard deviation, Co-Cr: Cobalt-chromium alloy

Table 2: One-sample *t*-test showing the mean difference of the samples from two groups

Metal types	*t*	df	*P*	95% CI (lower bound-upper bound)
Co-Cr	10.173	19	<0.001	18.992-28.832
Titanium	9.046	19	<0.001	22.867-36.635

Co-Cr: Cobalt-chromium alloy, CI: Confidence interval

In the present study, adhesion between titanium-ceramic and chrome-cobalt-ceramic was determined in terms of SBS and it can be concluded as follows:

1. The adhesion between titanium-ceramic surface treated with aluminum oxide and bonding agent has higher bond strength than Co-Cr-ceramic
2. The nature of metal intermediate bonding agent, porcelain bonding, was both mechanical and chemical. The failure in all systems was cohesive and adhesive, predominantly cohesive as observed under SEM.

Literature suggests that, of all the tests such as flexure strength tests, tensile tests, and shear tests, the use of SBS test to determine core-veneer bond strength yields more standardized data as the applied forces are perpendicular to the bonding area. In addition, the small cross-sectional area of the bonded surface in SBS eliminates the possible incorporation of structural flaws, which significantly affects the test results.[8]

Previously, Olivieri *et al*.[9] performed a study to evaluate SBS of gold and titanium and also analyze bonding interface using SEM. Twelve specimens each of gold and titanium were prepared. All the samples were layered with ceramic and subjected to shear bond test. They concluded that titanium has better bond strength compared to gold. Akova *et al*.[10] conducted a study to compare SBS of laser sintered Co-Cr alloy and cast base metal dental alloys: Ni-Cr and Co-Cr. Ten specimens were prepared for each group, layered with dental porcelain, and subjected to shear bond test in universal testing machine. It was concluded that SBS was highest for Co-Cr specimens fabricated by casting method.

While interpreting the study results, it should be noted that the present results were obtained *in vitro*, with the consequent risk of presenting too simplified a picture. However, some thoughts on possible clinical implications are appropriate. The findings of the present *in vitro* study

Table 3: Paired-sample *t*-test showing the mean difference of the samples from two groups

Metal types	Mean	SD	SEM	95% CI (lower-upper)	*t*	df	*P*
Co-Cr versus titanium	−5.839	17.9738	4.01907	−14.251-2.573	−1.453	19	0.163

Co-Cr: Cobalt-chromium alloy, CI: Confidence interval, SD: Standard deviation, SEM: Standard error of mean

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can be extrapolated to clinical practice. Clinical applications of the findings include the use of titanium-ceramic alloy (surface treated with aluminum oxide and bonding agent) for an implant superstructure in routine clinical practice.

Further studies that compare this alloy with other metal combinations in terms of various physical and biological properties are recommended with research designs that provide a higher level of evidence than an *in vitro* study.

CONCLUSION

Obtaining suitable bonding of titanium and its alloys as metal substrate and dental porcelain is very crucial. According to this study, the SBS of ceramic-veneered over titanium meets the ISO requirements of minimum SBS between metal-ceramic systems and has achieved the clinically acceptable values. Therefore, using titanium super structure rather than any other metals over titanium implants reduces the adverse effects and avoids undesirable effects.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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