Original Article

Comparative evaluation of bonding strength of computer aided machined ceramic, pressable ceramic, and milled metal implant abutment copings and effect of surface conditioning on bonding strength: An *in vitro* study

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Abstract

Background/Purpose: The aim of this study was to compare the shear bond strength of computer aided design/computer aided machined ceramic (CAD/CAM), pressable ceramic, and milled metal implant copings on abutment and the effect of surface conditioning on bonding strength.

Materials and Methods: A total of 90 test samples were fabricated on three titanium abutments. Among 90 test samples, 30 copings were fabricated by CAD/CAM, 30 by pressable, and 30 by milling of titanium metal. These 30 test samples in each group were further subdivided equally for surface treatment. Fifteen out of 30 test samples in each group were surface conditioned with airborne particle abrasion. All the 90 test samples were luted on abutment with glass ionomer cement. Bonding strength was evaluated for all the samples using universal testing machine at a crosshead speed of 5 mm/min. The results obtained were compared and evaluated using one-way ANOVA with *post-hoc* and unpaired *t*-test at a significance level of 0.05.

Results: The mean difference for CAD/CAM surface conditioned subgroup was 1.28 ± 0.12, for nonconditioned subgroup was 1.20 ± 0.11. The mean difference for pressable surface conditioned subgroup was 1.18 ± 0.04, and for nonconditioned subgroup was 0.75 ± 0.28. The mean difference for milled metal surface conditioned subgroup was 2.57 ± 0.58, and for nonconditioned subgroup was 1.49 ± 0.15.

Conclusions: On comparison of bonding strength, milled metal copings had an edge over the other two materials, and surface conditioning increased the bond strength.

Key Words: Bonding strength, computer aided design/computer aided machined, metal milling, pressable ceramic, surface conditioning

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INTRODUCTION

At present, implants have become a standard means of replacing missing teeth since they have the advantage of allowing preservation of the integrity of sound teeth adjacent to the edentulous area. The most widely used material for dental implants is titanium owing to its superior properties such as biocompatibility and corrosion resistant.[1]

After placement and osseointegration of implants, it is the responsibility of the dentist to maintain properly designed and fitted prosthesis.[2] Clinical decisions are not limited to the selection of the type of implant but are also dependent on the material of prosthesis. Regardless of the implant system used, a restoration is selected to emerge from the tissues to imitate a natural tooth.[3] The quest for predictable long-term results has raised several questions concerning the materials used as well as the techniques followed in clinical practice. Implant supported restorations can be fabricated by nonprecious alloys or all ceramic materials. In the recent scenario of advanced technology, recent progress in casting techniques as well as the introduction of computer aided design/computer aided machined (CAD/CAM) has made it possible to make the prostheses using titanium also. Titanium is particularly suitable for patients who are allergic to other metal alloys.[4]

CAD/CAM technology, all ceramic systems, and high strength ceramic materials have become integral parts of modern dentistry. Optimal esthetics and characteristics such as color stability, high wear resistance, and low thermal conductivity make all ceramic materials ideal for the fabrication of dental prostheses.[5] The main advantage of all ceramic systems lies in the absence of metal, especially in cases with very thin tissue thickness and shallow implant depths allowing a more esthetically pleasing restoration.

Dental implant restorations can be cement retained, screw retained or a combination of both. Because it is difficult to achieve passive fit with screw-retained implant restorations, some dentists prefer cemented prosthesis.[6] On the other hand, cement retained prosthesis has the disadvantage of compromised stability in case of less interocclusal distance, as the abutment lacks the height and taper for cement retention.[7] Retention should be considered for cement retained prostheses for its removal for future maintenance. Retrievability also serves as the safety mechanism to allow the prosthesis to be removed without causing harm to underlying implant superstructures.[8]

Retention certainly influences the lack of complications as well as the longevity of implant prostheses. Over the years, those engaged in implant supported restorations have debated as to which type of mechanism is preferable for increase bonding of cemented restorations.[9] The success of implant-supported restorations depends on the success of bonding between prosthesis and metal interface. Retention of crown depends on cement used, surface preparation of the implant abutment, and other variables such as internal surface characteristics of coping and the height and taper of implant abutment.[8] For better simulation of clinical conditions, investigation of the bonding or retentive strength should be studied using axial dislodgment forces.[10] Numerous studies investigating the bonding strength of different luting agents on retention of cement-retained prosthesis and also effect of airborne-particle abrasion on zirconia copings are available, but there is a paucity of studies having direct comparison of different copings to the best of our knowledge.

Due to the above concerns, there is a need for comparing the shear bond strength of abutment copings of different materials, made by different techniques as well as effect of surface conditioning on bonding. The null hypothesis was that there was no difference in bond strength of abutment copings made of different materials and also no effect of surface conditioning on bonding. The alternate hypothesis states that there was difference in bond strength of abutment copings, and also surface conditioning affected the bonding strength.

MATERIALS AND METHODS

Fabrication of copings

The present research is a cross-sectional *in vitro* study aimed to compare the shear bond strength of different copings and effect of surface conditioning on shear bond strength of three different types of abutment copings made on titanium implant abutment (Indident Dental Implant System, DRDO Inmas, New Delhi, India).

In the present study, three different types of abutment copings were fabricated on titanium implant abutment (Indident Dental Implant System, DRDO Inmas, New Delhi, India). The sample size was estimated to be 30 in each group based on previous studies.[11]

For Group A, 30 CAD/CAM zirconia copings were fabricated on one implant abutment [Figure 1a] using cercon CAD/CAM system (Dentsply, Germany). Scan spray containing silver particles was sprinkled on abutment. Optical scanning was done with cercon eye. Once the scanning was completed with cercon eye, cement gap, wall thickness, and occlusal geometry were adjusted for the coping with the help of cercon art program. A luting gap of 30 μm and wall thickness of 0.8 mm were chosen for the coping fabrication. Presintered zirconia blank of 38 size was inserted in cercon brain to complete the milling. After milling was completed, the frameworks of the coping were separated from the blank with the help of micromotor and

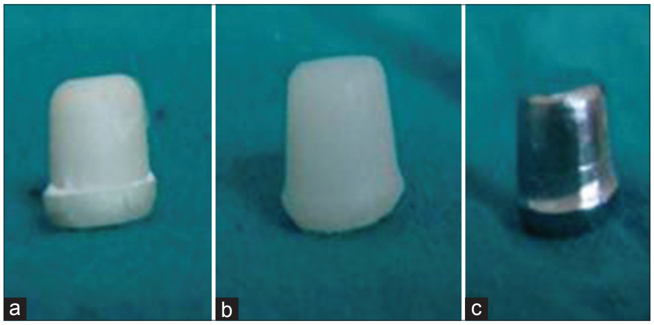


Figure 1: (a-c) Abutment copings made of computer aided design/computer aided machined (left), pressable ceramic (middle), and milled metal (right)

Figure 2: Metal milling of titanium blank for abutment copings

sintered in furnace, according to manufacturer's instructions. Dimensions of CAD/CAM coping was measured with digital caliper (Shenzhen YKS Technology Ltd., China).

For Group B, 30 pressable ceramic copings of similar dimensions as that of CAD/CAM copings were fabricated on implant abutment [Figure 1b]. (IPS E-max, Ivoclar Vivadent, Liechtenstein). Implant abutment was screwed on implant analog, and two coatings of die spacer (Durolan, DFS) were applied on implant abutment to attain the same cement space. To attain the similar dimension as CAD/CAM coping, silicon index was fabricated of CAD/CAM coping extending on the predetermined groove on implant analog. Molten inlay wax (Geo-dip, Renfert, Germany) was poured in silicon index, and mounted abutment was inserted in that index to the level of predetermined groove. Investment of wax pattern was done in silicone ring with the phosphate bonded investment material (IPS PressVEST Speed). The IPS E-max press ingot was inserted in hot investment ring. Investment ring was inserted in the center of hot press furnace (Multimat 2 touch + press) using investment tongs; selected program was started. After cooling of the ring, the sprue and reaction layer on the copings were removed, and copings were retrieved. Dimensions of pressable ceramic coping were verified with a digital caliper.

For Group C, 30 milled metal copings of similar dimensions as that of CAD/CAM copings were fabricated on implant abutment [Figure 1c]. The wax pattern was fabricated in the same manner as for pressable copings. Wax pattern was scanned in the computer true definition scanner (TDS). The CAD volume data was transferred to the multi-axis metal milling machine (TDS cutter, Turbodent system, Taiwan). Copings were milled from titanium blank using the existing data [Figure 2]. Copings were separated from the blank. Again, dimensions were verified using digital caliper.

Surface conditioning

Copings of CAD/CAM, pressable ceramic and metal millings were divided into two halves. To maintain standardization, same surface treatment was applied for copings. One-half (15 out of 30 samples in each group) was surface conditioned by air-abrasion with 50 μm Al_2O_3 at 2.5 bars pressure for 20 s at a distance of 10 mm in the sandblaster [Figure 3],[9] and other half were left nonconditioned. Thus, three groups with two subgroups of each of the copings were prepared:

- Group A (n = 30): Copings made by computer-aided technique
  - Subgroup A1 (n = 15): Copings made by computer-aided technique that were surface conditioned
  - Subgroup A2 (n = 15): Copings made by computer-aided technique that were nonconditioned
- Group B (n = 30): Copings made by pressable ceramic technique
  - Subgroup B1 (n = 15): Copings made by pressable ceramic technique that were surface conditioned
  - Subgroup B2 (n = 15): Copings made by pressable ceramic technique that were nonconditioned
- Group C (n = 30): Copings made by metal milling

  Subgroup C1 (n = 15): Milled metal copings that were surface conditioned

  Subgroup C2 (n = 15): Milled metal copings that were nonconditioned.

Cementation of copings

All specimens were cemented to titanium abutment using glass ionomer cement (GIC) (Meron, VOCO GmbH, Germany) to make standardization, which was mixed according to manufacturers' recommendations. An alignment apparatus [Figure 4] was used that applied a weight of 750 g to the bonded specimens. Extra cement was scraped out,[9] and after initial set (8 min), specimens were stored in distilled water for 24 h to simulate the moist oral environment.

Determination of bonding strength

In the present study, shear bond strength was evaluated by universal testing machine [Figure 5] (22.5 K Instron, model 4482). Forces were applied axially on coping cemented on abutment at a cross-head speed of 1.0 mm/min. A computer connected with the Instron machine recorded the result of each test. The nonadhesive chemical bond strength (∂) values (expressed in effects of MPa) were calculated using the formula: $\partial = L/A$.[9] Where L is load (in N) and A is the adhesive area (in m^2).[12]

Data analysis

The shear bond strength was evaluated by pull-off test for all the abutment copings. All calculations were performed using the SPSS (version 16) for windows (SPSS Inc., Chicago, IL, USA).

RESULTS

A one-way analysis of variance was computed for statistical significance at $P = 0.05$ for individual groups with *post-hoc* (Tukey's Honest Significant Difference) and intragroup comparison was done by unpaired *t*-test.

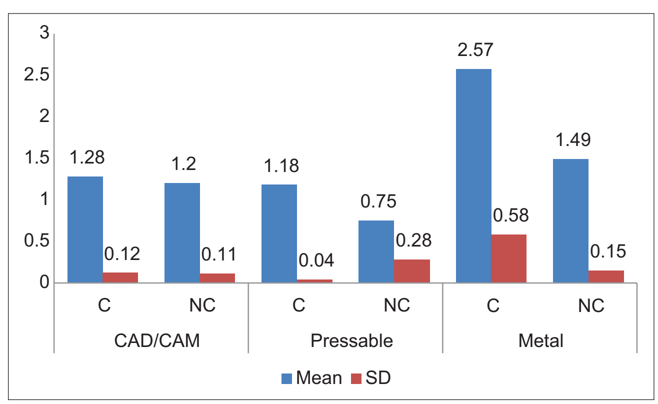
The mean difference for CAD/CAM surface conditioned group was 1.28 ± 0.12, for nonconditioned group was 1.20 ± 0.11. The mean difference for pressable surface conditioned group was 1.18 ± 0.04, and for nonconditioned group was 0.75 ± 0.28. The mean difference for milled metal surface conditioned group was 2.57 ± 0.58, and for nonconditioned group was 1.49 ± 0.15 [Graph 1 and Table 1].

On intragroup comparison, results showed that pressable ceramic and milled metal group had the statistically significant difference ($P = 0.05$) in conditioned and nonconditioned specimens [Table 2]. Bonding strength was highest for milled metal surface conditioned group. The least bonding strength was found for pressable nonconditioned group. The mean bond strength value with air abrasion specimens was higher. On intergroup comparisons, CAD/CAM, pressable, and milled metal surface conditioned specimens had statistically significant difference, and similar results were found for nonconditioned specimens [Table 3].

Figure 3: Surface conditioning done by air-abrasion with 50 μm Al_2O_3 at 2.5 bars pressure for 20 s

Figure 4: Alignment apparatus applying a weight of 750 g to the bonded specimens

Figure 5: Pull-off test for determination of bonding strength



Graph 1: Mean and standard deviation of bonding strength (in MPa) between surface conditioned (C) and nonconditioned specimens (NC)

Table 1: Mean bonding strength (in MPa) of different specimens

Groups	Number of specimens	Mean bond strength in MPa	SD
A1. CAD/CAM surface conditioned	15	1.28	0.12
A2. CAD/CAM nonsurface conditioned	15	1.20	0.11
B1. Pressable ceramic surface conditioned	15	1.18	0.04
B2. Pressable ceramic nonsurface conditioned	15	0.75	0.28
C1. Milled metal surface conditioned	15	2.57	0.58
C2. Milled metal nonsurface conditioned	15	1.49	0.15
ANOVA value	8.508		
Significant	0.000*		
Post-hoc comparison	Ca ≥ Aa, Ab, Ba, Bb, Cb, Cb ≥ Bb		

*The mean difference is significant at the 0.05 level. SD: Standard deviation, CAD/CAM: Computer aided design/computer aided machined, ANOVA: Analysis of variance

Table 2: Mean comparison and standard deviation of bonding strength(in MPa) between different abutment copings

	n	Mean	SD	SEM	*P*
CAD/CAM					
Conditioned	15	1.28	0.12	0.03	0.05
Nonconditioned	15	1.20	0.11	0.03	
Pressable					
Conditioned	15	1.18	0.04	0.01	0.01*
Nonconditioned	15	0.75	0.28	0.07	
Milled metal					
Conditioned	15	2.57	0.58	0.15	0.01*
Nonconditioned	15	1.49	0.15	0.04	

Significant at the level of 0.05, SD: Standard deviation, SEM: Standard error of mean, CAD/CAM: Computer aided design/computer aided machined

Table 3: Mean comparison of bonding strength (in MPa) between surface conditioned and nonconditioned specimens

	n	Mean	SD	SE	*P*
Conditioned					
CAD/CAM	15	1.28	0.12	0.03	0.00*
Pressable	15	1.17	0.04	0.01	
Milled metal	15	2.57	0.58	0.15	
Nonconditioned					
CAD/CAM	15	1.20	0.11	0.03	0.00*
Pressable	15	0.75	0.28	0.07	
Milled metal	15	1.49	0.15	0.04	

Significant at the level of 0.05, SD: Standard deviation, SE: Standard error, CAD/CAM: Computer aided design/computer aided machined

DISCUSSION

This study assessed the bonding strength of copings made out of different materials and also evaluated the effect of surface conditioning on bonding strength. The results of this study led to the rejection of null hypothesis that there was no significant difference in the bond strength of tested groups. Metal copings fabricated by milling technique provided much stronger retention as compared to other materials and also surface conditioning increases the bonding strength.

Two all ceramic materials and titanium metal were used in this study, and titanium metal was not casted because milling of titanium metal overcomes the problem of production of reactive surface layer on its surface when cast in thin and fragile sections.[13]

Over the years, questions have been put on bonding of implant supported restorations.[3] In order to improve bonding, the internal surface of restoration may be modified chemically or mechanically. This helps to promote surface roughness of restoration and reactivity to the luting agent. Chemical surface treatments include the use of various reactive agents while mechanical procedures include airborne-particle abrasion with alumina particles and abrasion with a mounted stone.[14]

Cornelia Schiessl *et al.*[15] investigated the factors which determine the retentiveness of copings made out of Co-Cr alloy and zirconia luted with permanent and provisional luting cements. The conclusion of this study was that copings made of metal alloy and zirconia showed no different level of retentiveness when set onto titanium abutments fixed with permanent or provisional cements. As concluded in this study, surface conditioning with airborne particle abrasion enhances the bonding of metallic as well as ceramic-based restorations. Tashkandi[11] evaluated the effect of surface treatment on micro-shear bond strength of zirconia frameworks. He concluded a better bond strength in combination with air-abrasion. This was in agreement with other studies (Bottino *et al.* 2005).[16]

Ebert *et al.* in 2007[9] found similar results when evaluating the effect of two surface conditioning methods and two luting gap sizes on the bonding of zirconia copings. He found that air-abraded copings increased the retention. Airborne-particle abrasion has also been recommended as the best method of pretreatment in previous studies to improve the bond strength to oxide ceramics. Sadig and Al Harbi[17] compared the effect of different surface conditions on the retentiveness of titanium crowns cemented abutments using two types of cement. Results showed that sandblasted castings and pretreatment of abutment exhibited the greatest retentive strength. Shahin and Kern[18] in 2010 also concluded that air-abrasion significantly increases crown retention.

In the present study, GIC was used to cement milled metal and all ceramic copings. Although resin cements has got the maximum retention for all ceramic restorations, previous studies assessed that GIC has also got the adequate retention.[19] Maeyama *et al.*[20] compared the retentive strength of metal copings on prefabricated abutments with five different luting agents. GIC has got the sufficient retentive strength for luting cement retained superstructures.

GIC was used for luting all the specimens to make standardization, and moreover different resin cements require different pretreatment which could alter results. GIC show high water solubility and require sufficient time for complete setting reaction to maximize their retention. Manufacturer of GIC states that the material will reach its full set in 4–7 min so 8 min setting period that was allowed in the previous study should prove satisfactory.

The limitations of this study include that all copings were produced and tested under ideal conditions, which may not reflect conditions in daily clinical practice. Thermal cycling and long-term water storage are the factors that can have effects on the durability of bond strength,[10] and they are important parameters to simulate the oral conditions. In terms of *in vivo* loading, the masticatory cycle consists of combination of vertical and lateral forces, subjecting the restoration to a variety of off-axis loading. In the current investigation, the cemented copings were subjected to only axial forces. No single *in vitro* test provides an accurate indication of the intraoral environment.[3] Hence, future studies should attempt to simulate intraoral conditions, as well as utilize additional mechanical tests, which can provide a more reliable assessment of retention.

CONCLUSIONS

Within the conditions and limitations of this *in vitro* study, milled metal copings had the highest bond strength as compared to CAD/CAM and pressable ceramic copings. Surface conditioning with air-abrasion achieved better bond strength of all type of copings. Further studies are needed to evaluate optimal surface conditioning in order to enhance the longevity of restorations clinically.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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