Original Article

Effect of sandblasting on fracture load of titanium ceramic crowns

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Abstract

Purpose of the Study: It is difficult to achieve a reliable bond between the titanium and veneering porcelain. The aim of this study was to evaluate the bond strength between titanium ceramic crowns.

Materials and Methods: The surfaces of titanium copings were divided in two groups. Group A sandblasted with 250 um ($n = 10$) and Group B without sandblasting ($n = 10$). Low-fusing porcelain was bonded over copings. A universal testing machine was used to determine the fracture load (N) of the crowns. All data were compared using Student's t-test.

Results: There was a significant difference in fracture toughness between two groups ($P = 0.05$). The mean value of fracture strength for Group A was 721.66 N and for Group B was 396.39 N.

Conclusions: Sandblasting improves the bond strength between titanium, and ceramic, mechanical bonding plays a crucial role in the bonding between titanium and ceramic.

Key Words: Bonding, fracture load, sandblasting, titanium

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INTRODUCTION

Metal-ceramic restorations combine the esthetic advantages of ceramics with the durability and marginal fit of cast substrates.[1] In recent years, titanium has become a material of great attention in dentistry, because of its good biocompatibility and mechanical properties. The high melting temperature and violent chemical reactivity at high temperature of titanium and its alloys result in difficulties with casting and cause problems, when dental ceramics are fused to titanium.[2,3] Thus, although commercial titanium ceramic systems are available today, they still have unsolved problems related to the fusing of dental ceramics to titanium. The low bond strength of titanium ceramic restorations is caused by the excessive titanium oxide layer that forms during the porcelain firing stage. Various pure metals and ceramics have been used to coat the titanium surface to prevent oxidation during firing. Park *et al.*[4] reported that adhesion between the titanium and ceramic was increased by coating the former with gold (Au) or titanium nitride (TiN). Wang *et al.*[5] reported that a silicon nitride coating as an oxygen-diffusion barrier significantly improved the bond strength between titanium and ceramic. Oshida *et al.*[6] observed similar improvement with a TiN coating. The use of gold-coated titanium surfaces and firing porcelain in an argon atmosphere have been reported to increase the bond strength between titanium and ceramic.[7,8] Therefore, the purpose of this study was to investigate the effect of sandblasting on the bond strength between the titanium and porcelain components of crown restorations. The null hypothesis was that sandblasting would not affect the bond strength between the titanium and porcelain components of crown restorations.

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MATERIALS AND METHODS

A mandibular first premolar was carved on inlay wax (S.U. Inlay Wax, Germany) with dimensions cervico-occlusal length 8.5 mm mesiodistal dimension 7.0 mm, labiolingual dimension 7.5 mm. Based on this carved mandibular first premolar was made in such a way that carved crown was in the center. Crown was then reduced by 1.5 mm on the occlusal, proximal, buccal, and lingual surfaces, with a 1.0-mm shoulder margin prepared for a metal ceramic crown all sharp angles were rounded and the dimensions after reduction were verified with the help of divider and metal scale [Figure 1]. The prepared wax pattern was sprued [Figure 2] and invested with Phosphate bonded investment (Bellasum, Bego, Germany). Specimen was then cast in a Ni-Cr alloy (Remanium Dentaurum, Germany) with a centrifugal casting machine (Degutron, Degussa, Germany) for the fabrication of metal die. Casting was thoroughly cleaned using abrasive with the help of 250 µm aluminum oxide (Aluminox Delta) in the sandblaster unit (Type 5417-Kavo EWL, Germany). The die was polished using polishing buff [Figure 3].

Figure 1: Wax pattern of prepared premolar

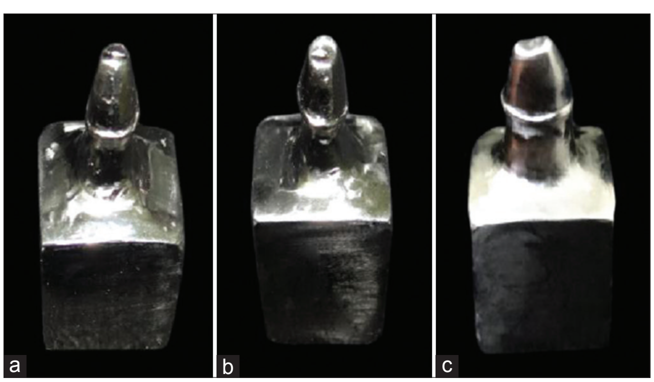


Figure 3: Metal die. (a) Abial view of metal die. (b) Lingual view of metal die. (c) Proximal view of metal die

Totally, 20 impressions of the metal die were made with addition silicone – putty consistency (DENTSPLY, Germany). These impressions were then poured in dental stone type-4 (Neelkanth, India) [Figure 4].

A total of 20 wax patterns were fabricated with inlay wax (S.U. Inlay Wax, Germany) over the dies following the contour of the prepared crown. These wax patterns were sprued and were invested with silica and phosphate-free, alumina- and magnesia-based investment (Rematitan Plus; Dentaurum, Pforzheim, Germany). For casting a centrifugal titanium casting unit Speed cast (model 220 MJ Ti by Orotig,) was used. Twenty titanium copings with thickness of 0.3mm were made from Cp-Ti Grade II (Orotig Srl, Italy). The combined presence of Argon gas and the firing of flasks at relatively low temperature allow getting very compact oxide-free cast metal.

The irregularities in the titanium copings were eliminated by airborne-particle abrasion using 50 µm Al_2O_3 particles at a pressure of 0.4 MPa for 10 s, at a direction perpendicular to the surface and at a distance of 10 mm using an airborne-particle-abrasion device (Type 5417-Kavo EWL, Germany). After removing the investment, the copings were cleaned by ultrasonic debridement, first in distilled water for 5 min and then in acetone for 5 min, and dried thoroughly. 10

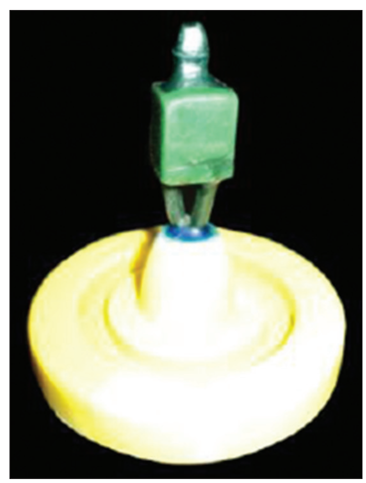


Figure 2: Spruing of wax pattern

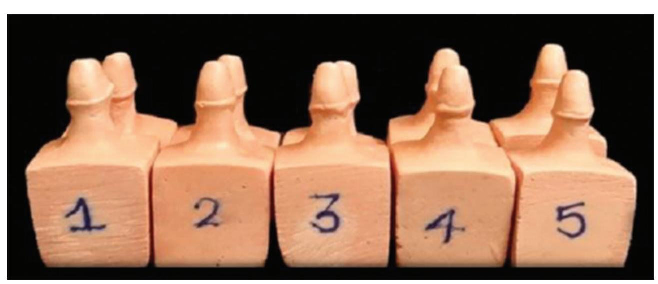


Figure 4: Stone die

titanium copings were airborne-particle abraded with 250 μm Al_2O_3 particles for 20 s [Figure 5]. A constant pressure of 0.55 MPa was used for Airborne-particle-abrasion and the distance between the surface and the nozzle was 1.0 mm. The remaining 10 titanium copings were not Sand blasted [Figure 6].

Ultra-low-fusing porcelain (VITA Titanium Ceramic; VITA Zahnfabrick, Bad Sacking, Germany) was used to fabricate the titanium ceramic crowns [Figure 7]. Titanium copings were degassed at 500–800°C at heating rate of 50°C/min and held in furnace for 3 min under vacuum (9.8×10^{4}) and then application of a porcelain paste bonder was done to ensure good bonding, followed by two layers of opaque porcelain (Shade A-2). Once the opaque firing was completed two layers of the dentin porcelain. (Shade A-2) from classical standard kit.

A universal testing machine (STS-248 63, Schpura Indl. Estate, Mumbai, India) with special dies was used to determine the fracture load of the crowns. A stainless steel stylus with a 5-mm tip diameter was placed perpendicular to the buccal cusp of each metal ceramic crown.

A compressive load was applied at a crosshead speed of 3 mm/min until the porcelain began to detach from the metal, and the reading was recorded in Newton [Figure 8].

RESULTS

The fracture strength of the two groups was measured digitally using universal testing machine under compression. Table lists the descriptive statistics, including the mean fracture load and standard deviation (SD) values of two groups. The mean fracture load was 721.66 N and 396.39 N for titanium ceramic crowns with sandblasting and without sandblasting, respectively.

According to the *t*-test, there is statistical significant difference between two groups ($P = 0.05$). The Group A has fracture toughness almost twice that of Group B. The labial porcelain under the buccal cusp was detached perpendicularly by the load. The two types of crowns showed different fracture patterns.

Group A fracture occurred primarily within the porcelain or between the opaque porcelain and coping and sufficient amount of porcelain was attached to the titanium coping as compare to without sandblasted coping from which ceramic was completely detached [Figure 9]. This fracture pattern reveals more of cohesive failure in Group A whereas more of adhesive failure in Group B [Graph 1].

DISCUSSION

The null hypothesis was that sandblasting with Aluminum oxide would not affect the bond strength between the titanium

Group	Mean	SD	*t*
A	721.66 *n*	70.53	8.34
B	396.39 *n*	93.39	

SD: Standard deviation

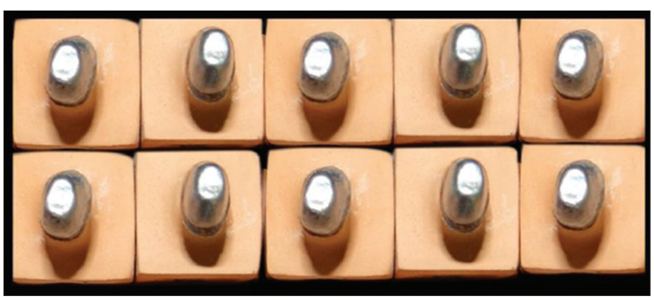


Figure 5: Titanium copings without surface treatment

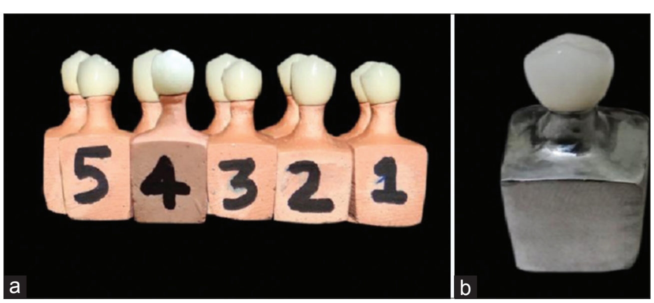


Figure 7: (a) Titanium ceramic crowns on stonem die. (b) Titanium ceramic crowns on master die

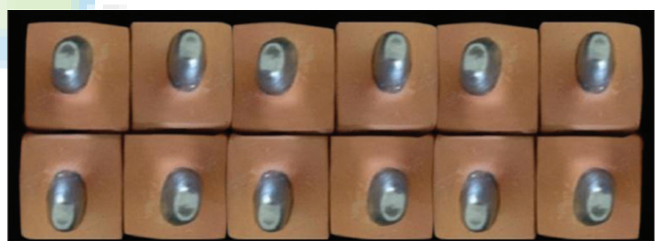


Figure 6: Titanium copings with 250 um Al2O3 surface treatment

Figure 8: Specimen on universal testing machine

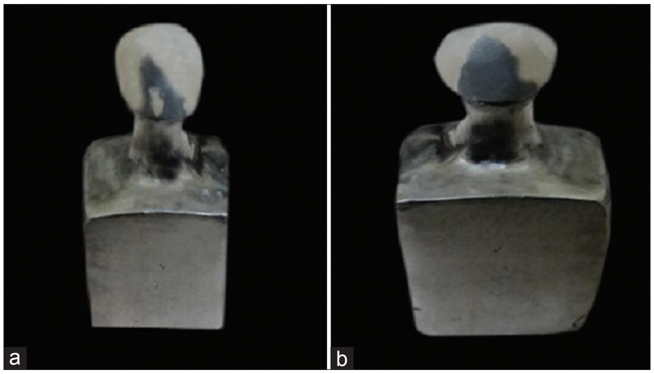
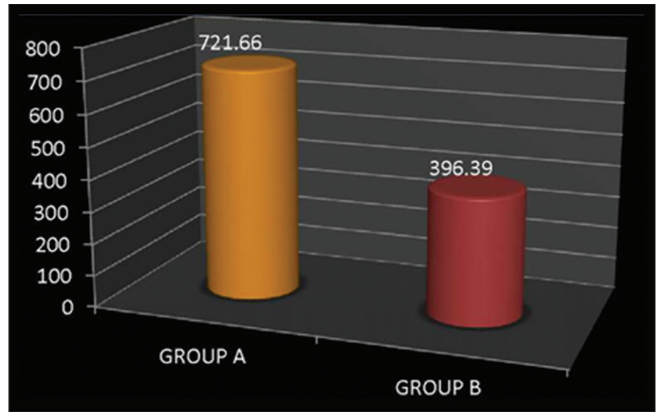


Figure 9: (a) Fractured Specimen of Group A. (b) Fractured Specimen of Group B



Graph 1: X axis showing the two groups Y axis showing the mean fracture load

and porcelain components of crown restorations. The results support rejection of this null hypothesis because Aluminum oxide surface treated had a significantly higher fracture load than the titanium ceramic crowns that had been not airborne-particle abraded with Al_2O_3 particles.

The searches for alternatives capable of satisfactorily replacing the traditionally used alloys made titanium a target for researches in prosthetic dentistry. Bio-compatibility, resistance to corrosion, low specific weight, ductility and low heat conductivity of titanium are the attractive properties.[3,9] The strength of the titanium-porcelain combination depends on the effects of oxidation that occurs at the interface. When working with temperatures between 700°C and 800°C, it is possible to obtain an unacceptable bond. Values that are close to or exceed 900°C promote the formation of a thick layer of oxide (TiO_2) between the porcelain and the metal, making the union unfeasible.[2,10] Residual stress and fractures are facts strictly related to the difference of thermal expansion between the metal substrate and the porcelain. In order for them to be compatible, the difference in the thermal expansion coefficient between the materials should be equal to or less than 1× 10-6/°C.[11] Titanium has a thermal expansion coefficient of 9.41 × 10× -6/°C, in the interval of 25–400°C.[12] The thermal expansion coefficient of the porcelain Vita Titanium ceramic used in this study according to its manufacturer is 8.2–8.9 × 10-6/°C,/°C. Although the results of these previous studies suggest that various surface treatments of titanium have an important role in enhancing the titanium/porcelain bond, there is some uncertainty as to how well such treatments work when used for a clinical titanium crown; as most of these studies were limited to coating flat titanium surfaces, none of these reports discussed the adhesion between the titanium and the porcelain components of crown restorations. Hence, an ideal mandibular premolar was taken as a test sample to simulate clinical condition.

Improving the bond strength of porcelain to titanium is important for enhancing its clinical usability. Surface treatment with sandblasting effectively enhance the bond strength with porcelain.[13,14]

Reyes *et al.*[15] Airborne-particle abrasion likely improves the bond strength by removing loosely attached furrows, overlaps, and flakes of metal created by grinding procedures, provides mechanical interlocking, increases surface area, and increases wettability. The means of fracture load of titanium and ceramic in sandblasted sample was 721.66 N and of the sample which was not sandblasted was 396.39 N. The fracture loads obtained in this study suggest that the adhesion of porcelain to titanium can be improved by surface treatment modified titanium surface, and the surface not receiving airborne-particle abrasion or bonding agent, may lead to an unsatisfactory titanium-ceramic bond. This is in agreement with previous studies.[15-18] Wang and Fung have indicated that the unmodified titanium surface produces a weak, porous, nonproductive and nonadherent oxide layer that is unsuitable for porcelain bonding.

Titanium as a biomaterial will probably continue to predominate in treatments involving osseointegrated implants. In order for usual prosthetic constructions to become accessible and reliable, further clinical research and longitudinal studies are necessary. However, the bond of ceramic to titanium is a sensitive technique influenced by the effects provoked mainly by the layer of surface oxide. The factors involved in the formation and modification of this layer should be observed and respected. The surface treatment applied to the substrate, the size of the aluminum oxide particles used for sandblasting, as well as adequate waiting time between sandblasting and applying the ceramic, should be considered.[19,20] Furthermore, it is evident that the attempts to improve the bond strength of the set by applying chemical elements over the titanium are valid.[5,21] The future of cast titanium restorations is bright, but there are still many questions to be answered before titanium can be considered to be the material of choice in the restoration of the coronal portions of the dentition.

A limitation of this study was that only 1 brand of low-fusing porcelain and 1 brand of titanium were tested; the findings related to these 2 products may not be extrapolated to similar materials. Furthermore, if measuring the oxide layer thickness had been part of the study, helpful observations might have been obtained to better understand the behavior of the materials.

CONCLUSIONS

Titanium-ceramic bonding is an unsolved problem because of relatively low thermal expansion/contraction coefficient of titanium and excessive and nonadherent titanium oxide scale formation during ceramic firing. The purpose of this study was to investigate the bond characteristics between titanium and ceramic with and without surface treatment. This study examined the effects of Al_2O_3 (250 um) airborne-particle abrasion, on the fracture load between the low-fusing porcelain and casting commercially pure titanium. Within the limitation of this study it can be concluded that

- The results of fracture load showed that the bond strength values of cp titanium-ceramic with aluminum oxide was significantly greater than without sandblasted group. The increase in fracture toughness by sandblasting was almost twice as compared to no surface treatment group
- Mean value for Group A (sandblast treated) was 721.66 N and for Group B (without surface treatment) was 376.39.
- The mode of failure for both the groups was mixed but for sandblasted group it was mainly cohesive whereas for without surface treated sample was adhesive in nature
- Mechanical bonding plays a crucial role in titanium ceramic bonding
- Sandblast pretreatment of titanium is simple and easy method to increase of effective surface area and improving the wetting ability of porcelain before bonding porcelain.

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