

Comparative assessment of marginal accuracy of grade II titanium and Ni–Cr alloy before and after ceramic firing: An *in vitro* study

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ABSTRACT

Objective: The aims of the study are to assess the marginal accuracy of base metal and titanium alloy casting and to evaluate the effect of repeated ceramic firing on the marginal accuracy of base metal and titanium alloy castings. **Materials and Methods:** Twenty metal copings were fabricated with each casting material. Specimens were divided into 4 groups of 10 each representing base metal alloys castings without (Group A) and with metal shoulder margin (Group B), titanium castings without (Group C) and with metal shoulder margin (Group D). The measurement of fit of the metal copings was carried out before the ceramic firing at four different points and the same was followed after porcelain build-up. **Results:** Significant difference was found when Ni–Cr alloy samples were compared with Grade II titanium samples both before and after ceramic firings. The titanium castings with metal shoulder margin showed highest microgap among all the materials tested. **Conclusions:** Based on the results that were found and within the limitations of the study design, it can be concluded that there is marginal discrepancy in the copings made from Ni–Cr and Grade II titanium. This marginal discrepancy increased after ceramic firing cycles for both Ni–Cr and Grade II titanium. The comparative statistical analysis for copings with metal-collar showed maximum discrepancy for Group D. The comparative statistical analysis for copings without metal-collar showed maximum discrepancy for Group C.

Key words: Ni–Cr (Nickel–Chromium), titanium, titanium casting

INTRODUCTION

Although base metal alloys, such as nickel–chromium (Ni–Cr) and nickel–chromium–beryllium (Ni–Cr–Be) have been widely used in the fabrication of metal–ceramic crowns and fixed partial dentures, there are concerns about their biological safety following reports of nickel sensitivity in patients.^[1] Nickel is considered one of the most common causes of allergic dermatitis and is responsible for more allergic reactions than all other metals combined. Beryllium, present in many alternative alloys, improves castability of Ni–Cr alloys

by forming a low melting point of eutectic Ni–Be constituent. Unfortunately, beryllium is considered a potential carcinogen, presenting a problem for dental laboratory technicians because beryllium is released during casting and finishing procedures.^[2]

Titanium is one of the strong contenders in this race. This is because of the unique physical characteristics of titanium alloys such as, biologic compatibility, ease of machining, high modulus of elasticity, low mass, high mechanical strength and resistance to corrosion. The increase in use of titanium in endosseous implant has also given rise to the use of titanium as a material for

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prosthetic superstructures.^[3-5] However, the problem areas for titanium when used in metal-ceramic restorations occur with casting and titanium-porcelain bonding.

The marginal fit of artificial crowns has been the focus of various investigations. The fit and distortion of metal-ceramic crowns, including the effects of repeated firing and various marginal designs, have been intensely scrutinized. A well-fitting crown reduces the chances of recurrent caries and periodontal diseases. Plaque accumulated in this space is responsible for inflammation of the periodontal tissues. Despite the fact that titanium and its alloys appear to be ideal replacements for noble alloys, they still present rather poor marginal fit compared with other alloys used for the fabrication of dental prostheses. The aims of the study are to assess the marginal accuracy of base metal and titanium alloy casting and to evaluate the effect of repeated ceramic firing on the marginal accuracy of base metal and titanium alloy castings. The objectives of the study are to choose a metal alloy material that will provide best marginal fit and to choose a material which will show least changes before and after repeated ceramic firing. Therefore an in-vitro study was designed to comparatively evaluate the marginal accuracy of the titanium and base metal casting alloy before and after repeated ceramic firing cycles.

MATERIALS AND METHODS

Materials used in this study were Ni-Cr (Cerabond 62.9% Ni, 23.0% Cr, 10% Mo) and Grade II titanium (Orotig 99.84% Ti, 0.18 O₂, 0.006% N, 0.004% C, 0.0006% H, 0.031% Fe) for the fabrication of metal coping. Total twenty metal copings were fabricated with each casting material, and specimens were divided into 4 groups of 10 each [Table 1]. Ivoclar Vivadent and Vita's Titankeramik were the ceramics used for veneering Ni-Cr and Titanium, respectively [Figures 1 and 2].

Groups	Firing sequence	No. of specimens
A	1 Oxidation, 2 opaque layers, 1 shoulder, 2 dentin layers, 1 glaze	10
B	1 Oxidation, 2 opaque layers, 2 dentin Layers, 1 glaze	10
C	1 Paste bonder, 2 opaque layers, 1 shoulder, 2 dentin layers, 1 glaze	10
D	1 Paste bonder, 2 opaque layers, 2 dentin layers, 1 glaze	10

Fabrication of stone die

The stainless steel die was duplicated in a low expansion die stone (Ultra Rock, Kalabhai, India) by fabricating an acrylic custom tray, with 1.5 mm wax spacer and a polyvinyl siloxane impression material (Exaflex, G.C. Corp.).

Wax pattern fabrication

Crown and bridge casting wax was placed in the stainless steel former and was melted with a torch. The lubricated stone die was positioned in the steel former. The die former assembly was held together for 1 minute and then immersed at room temperature water for 3 minutes. A total 40 stone dies and wax patterns were fabricated. They were divided into the following 4 groups consisting of 10 individual wax patterns and stone die each [Figure 3].



Figure 1: Materials used in the study



Figure 2: Materials used in the study

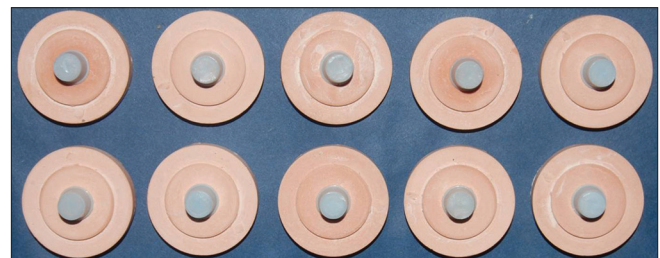


Figure 3: Fabricated wax patterns

Spruing of the wax patterns

A 12-gauge wax sprue with a reservoir located 3 mm from the end of the sprue was attached at a 45-degree angle to the occlusal surface of each wax pattern. The point of attachment was flared and not constricted. Each pattern was attached at a distance of 1 cm from the other. One pattern was invested per casting ring, with its open end parallel to the open end of the ring.

Casting procedure for titanium

The equipment utilized was a compact, bench top, titanium casting equipment. Prior to the casting a tungsten arc rod was adjusted using an alignment jig and a titanium ingot. The Argon gas (Inox-I, 99.99% pure) was used to create inert atmosphere to allow the arc to spark. By observing through the peephole provided the progress of the metal's melting was noted. The moment the ingot starts melting at 43 s, the casting button was pushed and held for 2 s. The chamber's box rotated pneumatically from the horizontal position to a vertical position in a fraction of second. The already molten titanium was instantaneously poured into the mould cylinder by the help of an argon gas overpressure, forced into in at 3.5-4.0 bars. The excess of investment material was removed. The copings were cleaned with fresh corundum 110 microns at 3-4 bars pressure. The copings were cut 1 mm short from the sprue end using a thin carborundum disc mounted on a high speed grinder (Ray Foster Corp) [Figure 4]. Any incomplete or defective castings noted were rejected from the sample.

Measurement of pre-veneered marginal discrepancy

Each casting was seated on its respective stone die under a constant load of 10 kg applied on the occlusal surface for 10 s. Grooves on the occlusal surface of the die prevented rotation of the casting and ensured seating of the crown at the same position as the wax pattern. Measurements were made using an optical microscope (Reichert, Austria), with an accuracy of 0.1 μ m. Measurements were made between the margin of the casting and the reference marks scribed on the die stone at four points, separated 90° apart. Measurements were done three times and an average value was recorded [Figure 5].

Firing cycles of porcelain

Following ceramic application (Ivoclar Vivadent, Mumbai, India) all the 40 samples were fired at the recommended temperature using the Multimat Ceramic Furnace (Dentsply, India) [Figure 6]. The firing sequence of the ceramic was followed as per standardized protocol [Table 1].

Measurement of the marginal accuracy after veneering

Each casting was seated on its respective stone die after the ceramic firing. Measurements were made using an optical microscope (Reichert, Austria), with an accuracy of 0.1 micron at the same points as earlier [Figure 7].

Statistical analysis

The continuous data was presented, mean and standard deviation was calculated. Analysis was done by SPSS Software version 10 by using Analysis of Variance (ANOVA). A "P value" less than 0.05 were considered as significant. The marginal accuracy of Ni-Cr alloy and Grade II titanium were evaluated before and after ceramic firing.

RESULTS

Comparison of marginal discrepancy before ceramic firing in all four study groups was done. It was concluded from the ANOVA test that Group D showed maximum marginal discrepancy (163.17 ± 45.47) before ceramic firing. It was found to be statistically significant [Table 2]. Comparison of marginal discrepancy after ceramic firing in all four study groups was done.

Comparison of mean marginal discrepancy before and after ceramic firing in Group A and Group C showed maximum value for Group C (221.05 ± 65.02) and minimum value for Group A (204.94 ± 39.22), with the 'P value' > 0.05, which is statistically insignificant. Also after comparing mean marginal discrepancy in Group B and Group D, it showed maximum value for Group D (238.52 ± 58.50) and minimum value for Group B (129.10 ± 20.30), with 'P value' < 0.0001 which is statistically highly significant.

The maximum mean marginal discrepancy before ceramic firing was found in Group D (163.17 ± 45.47) and minimum in Group B (101.89 ± 18.03). According to the ANOVA, the 'F value' was calculated out to be 6.07 which was statistically significant. The maximum mean marginal discrepancy after ceramic firing was found in Group D (238.52 ± 58.50) and minimum in Group B (129.10 ± 20.30). According to the ANOVA, the 'F value' was calculated to be 9.68 which was statistically highly significant.

DISCUSSION

The marginal integrity and fit of a crown margin is important to the long-term success of a cast

restoration.^[6] Clinical acceptability and longevity of cast restorations is related to marginal fit.^[7] This has been shown to be clinically significant to the periodontal health and development of recurrent marginal caries. Clinically, a cast alloy crown can be regarded as a good fit if it has sufficient axial tolerance to allow seating and if its margin is congruent with the cavo-surface line angle of the tooth preparation as judged by visual and tactile examination. However, there is no agreement in the definition of a clinically acceptable margin. The dimensions of a cast alloy crown are determined by the dimensions of the investment mould space into which the molten alloy is cast. If materials used during the casting process did not shrink or expand, the size of the final cast restoration would be the same as that of the original wax pattern. However, dimensional changes occur in most of the steps and,

in practice, the final restoration may not be exactly the same size as the pattern. The management of these dimensional changes is complex, but can be summarized by the equation:

$$\text{Wax Shrinkage} + \text{Metal Shrinkage} = \text{Wax Expansion} + \text{Setting Expansion} + \text{Hygroscopic Expansion} + \text{Thermal Expansion}$$

In addition, exposure of these castings to repeated firing for porcelain buildup leads to thermal distortion which again enhances the marginal misfit. Although researchers agree that deformation occurs during the porcelain firing cycle, considerable controversy continues to exist with regard to the real cause of this deformation.^[8] Several suggestions have been proposed to explain the distortion: (1) the design of the metal substructure; (2) contamination of the casting which reduces the melting temperatures and causes the grain of the alloy to grow; (3) relieving of casting induced stress; (4) contraction of porcelain

Table 2: Schematic distribution of samples

Group	Representation
A	Representing base metal alloys castings without metal shoulder margin
B	Representing base metal alloys castings with metal shoulder margin
C	Representing titanium castings without metal shoulder margin
D	Representing titanium castings with metal shoulder margin

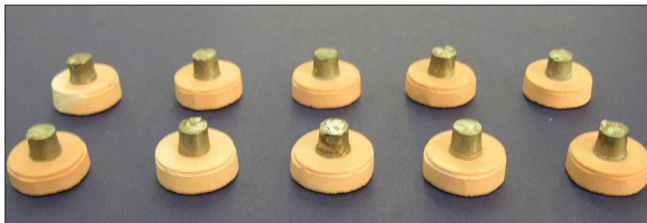


Figure 4: Copings after casting

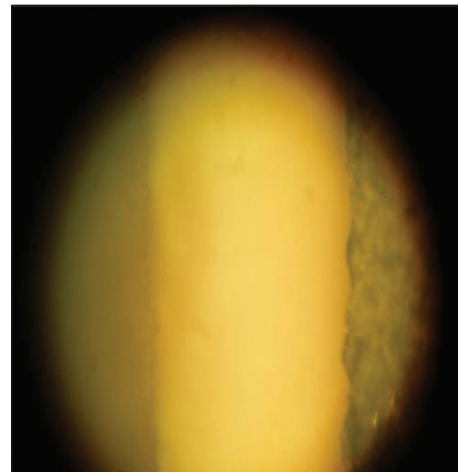


Figure 5: Marginal gap of coping under optical microscope

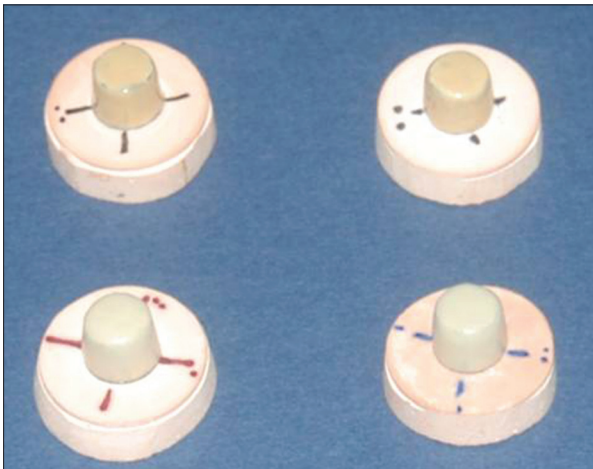


Figure 6: Samples after ceramic firing

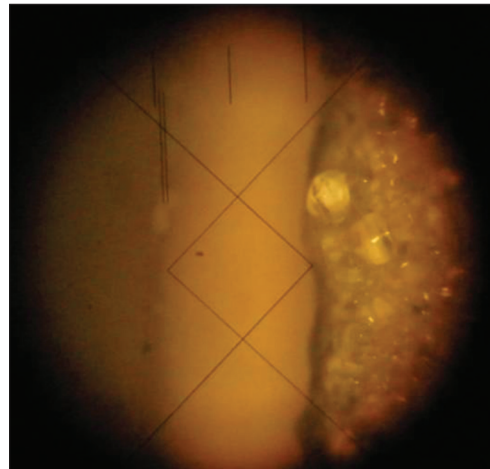


Figure 7: Marginal gap on optical microscope after ceramic firing

with subsequent metal deformation and (5) plastic flow and creep of the alloy at high temperature.

What is clear from the literature is the lack of agreement on the actual cause of the thermal cycling distortion of metal-ceramic restorations. The literature does indicate agreement in two areas: (1) distortion occurs during the thermal cycling process and (2) the timing of the deformation is such that most of it occurs during the initial oxidation of the alloy (before porcelain application).^[9,10] However, it has been observed that small changes continue during the subsequent heating and porcelain application.

The only known etiologic factors that can adequately account for the timing and magnitude of the observed distortion are: (1) release of stresses resulting from the solidification processes of the casting technique (for example, restriction of the alloy shrinkage in the casting investment) and (2) release of the stresses introduced by the cold working of the surface in preparation for porcelain application. While the other theories can contribute to the loss of fit, they cannot individually account for the magnitude and timing observed in metal frameworks.

The improvement in esthetics of cast restoration was done to labial veneering of ceramics. Light transmission properties in the cervical area of the restoration were not greatly improved, as incidental light failed to be transmitted through the entire body of the tooth due to presence of the lingual metal margin. The quest for improved esthetics led to circumferential collarless metal-ceramic restoration. The use of the porcelain labial margin was introduced in the 1970s.^[11,12] Several methods of porcelain margin fabrication have been reported, including the platinum foil and the direct lift techniques, with marginal accuracy comparable to that of metal margins. Bacterial plaque accumulation has also been reported to be less on porcelain margins as compared to metal margins. The porcelain labial margin has significantly improved the esthetics of metal-ceramic restorations. Treatment involving this type of restoration is time consuming, as the achievement of a clinically acceptable marginal fit often requires multiple firings. Nevertheless, with this technique, both diffuse transmission of the light from the crown to the root, as well as a reduction of the unaesthetic grayish shadow in the cervical area, can be achieved. Although the esthetic outcome of the collarless metal-ceramic restoration is better than the outcome with the metal margin, its mechanical strength has not been evaluated. Gardner *et al.*, in an

in vitro study tested the fracture load of metal-ceramic restorations with metal-collar margins in comparison to those with porcelain facial margins.^[11] The authors concluded that the load required for fracturing porcelain from crowns with facial porcelain margins was significantly greater than that for crowns with metal margins. Hence this study was designed to evaluate the effect of repeated porcelain firing cycles on the marginal accuracy of Grade II titanium and Ni-Cr alloys with metal shoulder margin and without metal shoulder margin in an *in vitro* environment.

Various investments also have recorded different types and magnitudes of distortion. The differences between investments, casting equipment, porcelain systems, and their firing temperatures for Cerabond metal-ceramic crowns and Orotig metal-ceramic crowns were inevitable because they were parts of two specific systems.

Any explanation of the etiology of thermal cycling distortion in metal-ceramic restorations must account for the observed magnitude, timing and direction of the deformation. For example, the theory that the porcelain firing shrinkage is a significant causative factor in the distortion process is questionable. This is because the timing of the distortion has been demonstrated to occur primarily during the initial oxidation process of the alloy (before porcelain application).^[9] Furthermore, the supposition that the densification shrinkage of the porcelain causes the metal to distort seems to predate the findings in the extensive literature currently available on dental porcelains. The temperature at which dental porcelain behaves as a viscous fluid has been determined to be between 600° and 700°C. This is well below the high temperatures (900°C to 1000°C for base metal alloys and 750° to 800°C for titanium) used for the densification firing of dental porcelain. At these elevated temperatures, it seems more likely that the porcelain would relieve the shrinkage stresses by flowing, rather than by stressing and distorting the alloy. The greatest magnitude of the observed distortion was clearly demonstrated to occur during the initial oxidation cycle of the alloys.^[10,13]

CONCLUSION

The results of the study substantiate the fact that the titanium can be cast and veneered with ceramic. The comparison of all four groups in statistical analysis showed that the marginal accuracy of titanium castings were inferior to that of the Ni-Cr alloy castings both

before and after ceramic firing. However comparison of two titanium groups showed that the marginal fit of titanium castings without metal-collar was superior to that of the titanium castings with metal collar.

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