Original Article

Braz J Oral Sci.
July/September 2010 - Volume 9, Number 3

# Porcelain application and simulation of firing cycle: effect on marginal misfit of implant-supported frameworks

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## Abstract

**Aim:** Success of implant-supported prostheses is related to the frameworks' passive fit, hence inaccuracies can generate stress, leading to bone resorption and rehabilitation failure. This study evaluated misfit levels of implant-supported frameworks after different coverage treatments. **Methods:** Twenty commercially pure titanium (CP Ti) frameworks were manufactured with 5 Branemark type multi-unit abutments. Frameworks were distributed in two groups as follows: G1 - porcelain application (n=10); G2 - porcelain firing cycle simulation (n=10). Using a traveling microscope, marginal misfit was measured before and after undertaking the techniques, following the single-screw test protocol. All data were submitted to ANOVA and Tukey's test ($p<0.05$). **Results:** Initial marginal misfit values were not significantly different, but both groups presented significantly higher misfit values after treatment: G1: 233.99 µm ($p=0.0003$); G2: 119.75 µm ($p<0.0001$). In addition, G1 presented higher misfit than G2 ($p<0.0001$). **Conclusions:** Porcelain application promoted significantly higher increase of misfit, which indicates that such procedure should be considered on misfit analysis of implant-supported prostheses.

**Keywords:** implant-supported prosthesis, prosthesis fitting, esthetic coverage, titanium framework.

## Introduction

Over the last 25 years, implant prostheses have become a frequent and reliable rehabilitation option for partially and completely edentulous patients[1-6]. After Branemark first started studying osseointegrated implants and the use of gold alloy frameworks in the early seventies[5,7], several studies have described the possibility of using other materials, such as cobalt-chromium alloy[8],silver-palladium alloys[9] and titanium[5].

Titanium presents great biocompatibility and corrosion resistance even in challenging environments such as the oral cavity, and was thus the first choice to fabricate dental implants. The success of titanium implants led to applying titanium for other purposes, such as manufacturing prosthetic frameworks[10-11].

Even though the bone-implant interface is extremely reliable, there are still some technical difficulties regarding the manufacturing process, which include the inability to make frameworks with intimate adaptation and to correct prosthesis misfit[2,9,12]. Frameworks without passive fit can generate stress between the

**Received for publication:** April 14, 2010
**Accepted:** July 06, 2010

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framework, prosthetic components and bone[13]. It can cause fracture of the prosthetic components, screw loosening and even induce bone resorption, leading to failure of the osseointegration[14-15]. Framework misfit occurs more frequently on multiple-element implant-supported prostheses[2,4-5,16].

Framework distortion can originate from waxing and inclusion processes[17], one-piece casting[18] and irregularities in margins and UCLA abutment screws[19-20]. Porcelain application can also increase distortion in implant-supported frameworks[21], depending on alloy type, porcelain contraction, thermal coefficients of the porcelain and alloy, and even framework design[17].

Since veneer application can promote distortion and misfit of implant-supported frameworks, the purpose of this study was to compare the effects of porcelain application and simulation of porcelain firing cycle on misfit of implant-supported Ti frameworks.

## Material and methods

Material specification, commercial brands and composition of the titanium alloy and porcelain employed in the present study are shown in Table 1.

A metal matrix containing 5 Branemark type implants (4.1 platform) with multi-unit abutments (Conexão Sistema de Próteses, Arujá, SP, Brazil) was molded using square transfers united with acrylic resin (Pattern; GC America, Alsip, IL, USA) and polyether (Impregum Soft; 3M ESPE AG, ESPE Platz, Seefeld, Germany). A casting mold was made containing the analogs, over which a ten element-fixed prosthesis framework with 10 mm cantilever was waxed using calcinable multi-unit copings (Conexão Sistema de Próteses). The waxed framework was duplicated using industrial silicone[22] to standardize frameworks (n=20). The silicone molds were then filled with plasticized wax, thereby producing identical specimens for casting, which was performed on a Rematitan machine (Dentaurum; Dentaurum J. P. Winkelstroeter KG, Pforzheim, Germany) using Tritan alloy.

A gypsum index was made for each framework to discharge from the measurements the misfit caused by the casting process. Since each framework was adjusted to its index, only the gap originated by the veneering techniques was measured. After the index was formed, initial misfit was measured.

A traveling microscope (Micro Vision; Leika, Wetzlar, Germany) with ×120 zoom and 0.05 μm precision was used to measure vertical linear dimensional alterations. Frameworks were positioned on the gypsum index and the single screw test protocol was followed. Screw from implant A was fixed with a torque control device (Conexão Sistemas de Prótese) using a 10 Ncm tightening force. This procedure allowed for checking the adaptation of the components on implants C and E. The protocol was repeated by tightening the screw of distal implant E and measuring the gap on implants C and A[13,17,21]. Measurements were taken three times on each implant (A, C and E) on buccal and lingual on diametric opposed sides.

Specimens were then distributed into groups for either porcelain application (G1) or simulation of the porcelain firing cycle (G2). G1 specimens were sandblasted with aluminum oxide spray with particles of 150 μm and 2.064 kgf/cm² pressure. Porcelain (Triceram; Dentaurum J. P. Winkelstroeter KG, Pforzheim, Germany) was applied using a silicone wall (Zetalabor; Zhermack, Rovigo, Italy) to standardize all prostheses. Firing cycles were the same for both groups and were performed as described by the porcelain's manufacturer, with G2 specimens being placed alongside G1 specimens for firing.

Marginal misfit was observed after porcelain application and simulation of the firing cycles following the single-screw test protocol (Figure 1). All data were analyzed statistically by repeated-measures ANOVA and Tukey's test ($p \leq 0.05$).

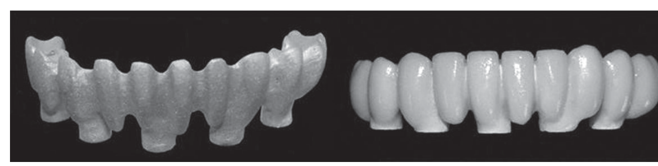

**Fig. 1.** Finished specimens: commercially pure titanium framework and framework with porcelain application.

## Results

Table 2 presents the mean marginal misfit values in μm (and standard deviations) of both groups, before and after treatment.

The porcelain group (G1) initially presented a mean misfit of 44.75 μm ± 13.73, and the group with simulated firing cycle (G2) presented mean misfit of 38.57 μm ± 16.94, and these values did not differ statistically from each other (p=1.000).

After treatment, both groups presented statistically significant higher marginal misfit values than initial ones: G1-233.99 μm ± 39.18 (p=0.0003) and G2-119.75 μm ±

**Table 2.** Marginal misfit (μm) before and after the treatments.

| Treatment | Initial Misfit | Misfit after treatment |
|---|---|---|
| Porcelain application | 44.75 (±13.73) Ba | 233.99 (±39.18) Aa |
| Firing cycles simulation | 38.57 (±16.94) Ba | 119.75 (±38.08) Ab |

Means followed by different lowercase letters in columns and uppercase letters in rows indicate statistically difference (Tukey's test; pd"0.05).

**Table 1.** Manufacturer, commercial brands and compositions of the materials used in the present study.

| Material | Manufacturer | Commercial Brand | Composition |
|---|---|---|---|
| Metallic Alloy | Dentaurum J. P. Winkelstroeter KG – Pforzheim - Germany | Tritan | 99.5% Ti; 0.25% O; 0.03% Ni; 0.3% Fe; 0.1% C; 0.015% |
| Porcelain | | Triceram | bonder, opaque, dentin I, dentin II, molding liquid |

38.08 ($p < 0.0001$). Comparing the groups after treatments, porcelain application group presented higher misfit values than the firing cycle simulation group ($p < 0.0001$).

## Discussion

Distortions in metal frameworks can compromise prosthesis adaptation. In the case of implant-supported prostheses, distortion can cause stress on the implant bone interface resulting in bone resorption and failure of the rehabilitation. In more severe cases, distortion can even cause failure of the implants.

Framework misfit of the implant platform might originate from several factors, one of which being porcelain application[21]. Several studies[9,23] have demonstrated that simulation of porcelain firing cycle can also increase misfit in implant-supported frameworks.

Initial misfit was measured considering that, even when polished, there is not a complete juxtaposition of the implant and framework surfaces, leaving a gap between the two. Initial misfit values were not statistically different between the two groups, which indicated a similarity between the frameworks after casting, allowing the comparison of the treatments effect to be made.

Both groups presented higher misfit values after treatment. Statistical analysis showed that this increase was significant for porcelain application (44.75 µm ± 13.73 to 233.99 µm ± 39.18; $p = 0.0003$) as well as for porcelain firing cycle simulation (38.57 µm ± 16.94 to 119.75 µm ± 38.08; $p < 0.0001$).

Frameworks that received porcelain application presented a greater increase in marginal misfit values than the ones submitted only to firing cycle simulation ($p < 0.0001$). This fact can be related to contamination of the framework's inner surface during application of the esthetic covering[24]. Since small amounts of porcelain tend to be translucent, their visualization is very difficult, making removal even harder. Residual porcelain could cause irregularities on the surface in contact with the implant and compromise implant adaptation.

Different contraction coefficients of the porcelain and the metal may also be responsible for deformation after application and firing. Furthermore, porcelain rigidity can compromise metal resilience[25], which could increase framework misfit.

Even though firing cycle simulation submits the metal framework to the effects of high temperature, some differences are encountered when porcelain is actually applied and not just simulated. These differences might be due to interactions between the materials. Buchanan et al.[25] observed that most framework misfit occurs after oxidation and glazing, due to the higher firing temperatures and cooling procedure of these steps. The slow cooling rate of frameworks during oven/vacuum processing favors the oxidation phase[26], which can increase metallic distortions.

Framework distortion after firing may be due to the high temperatures involved in the firing process or it may be due to alloy contamination during the casting process. Contamination may reduce the melting point of the alloy and promote grain growth[27]. Such phenomenon might explain the distortions presented by the simulation group.

In the present study, even the smallest deformation caused by porcelain application and firing cycles could present a significant increase in misfit due to the long extension of the frameworks, simulating a 10-element fixed implant-supported prosthesis.

It can be suggested that both porcelain application and firing cycle play important roles on framework misfit, since the final prosthesis results from the association of metal with an esthetic cover. Consequently, this association should be considered when studying the fit of alterations.

In conclusion, the present study demonstrated that simulation of the porcelain firing cycle does not replace porcelain application in analyses of prosthesis misfit. Since final misfit of the prosthesis is obtained after esthetic coverage, any modifications to the metal framework, such as porcelain application, would influence their final misfit. Due to different mechanical properties of the materials and possible contamination during the casting process, any changes in prosthesis fit might be considered to result from the association of porcelain application and firing cycle.

## Acknowledgements

This research was supported by FAPESP (grant 2004/13629-5).

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