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The effect of casting and masticatory simulation on strain and misfit of implant-supported metal frameworks

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ABSTRACT

The influence of casting and masticatory simulation on marginal misfit and strain in multiple implant-supported prostheses was evaluated. Three-unit screw retained fixed dental prosthesis (FDP) and screw retained full-arch fixed dental prosthesis (FAFDP) frameworks were made using calcinable or overcasted cylinders on conical dental implant abutment. Four groups were obtained according to the cylinder and prosthesis type ($n = 10$). Frameworks were casted in CoCr alloy and subjected to strain gauge analyses and marginal misfit measurements before and after 10^6 mechanical cycles (2 Hz/280 N). Results were submitted to ANOVA, Tukey's HSD and Pearson correlation test ($\alpha = 0.05$). No difference was found on misfit among all groups and times ($p > 0.05$). Overcasted frameworks showed higher strain than the calcinable ones (FDP — Initial $p = 0.0047$; Final $p = 0.0004$; FAFDP — Initial $p = 0.0476$; Final $p = 0.0115$). The masticatory simulation did not influence strain ($p > 0.05$). No correlation was observed between strain and misfit ($r = 0.24$; $p > 0.05$). In conclusion, the marginal misfit value in the overcasted full-arch frameworks was higher than clinical acceptable data. It proved that overcasted method is not an ideal method for full-arch prosthesis. Overcasted frameworks generate higher strain upon the system. The masticatory simulation had no influence on misfit and strain of multiple prostheses.

1. Introduction

The perfect fit between prosthetic framework and implant results in a lower amount of stress on the bone–implant interface [1,2]. Neglecting this factor can lead to biological or mechanical complications [3], even when external forces are not applied. Biological complications may include adverse tissue reactions, pain, tenderness, marginal bone loss, and loss of osseointegration [4]. Therefore, a passive relationship is a prerequisite for the long-term success of implant-supported rehabilitations [5].

The torque application in prosthetic screws of a non-passive framework generates bending moments and axial forces on the osseointegrated system [6,7]. This can lead to overload and/or fracture of components and retaining screws [4], micro fractures of cancellous bone, which can result in fibrointegration and loss of implant functionality [6]. Even though the dental implant rehabilitation can be considered a predictable treatment [8], complications can occur within the prosthesis, affecting the joint stability, which jeopardizes the predictability of treatment.

Nonetheless, the achievement of a passive framework is often limited by conventional casting techniques for obtaining prosthetic frameworks. The clinical and laboratory procedures involved in obtaining the prosthesis, even if properly executed, contribute to its final distortion [9]. The majority of the distortions occur due to volumetric change of materials and used techniques, such as impression material, plaster model, framework waxing, inclusion in investment, alloy casting, and veneering stage [9]. Therefore, the precision of casted frameworks is influenced by dimensional changes that occur during all stages of its fabrication [10].

The casting process is a potential agent for distortions that compromise the fit of the framework to the implant platform or abutments. In an attempt to minimize the changes resulting from the casting procedure, manufacturers developed dental implants abutments and cylinders with a metallic pre-machined strap, so that only the remainder of the cylinder body is plastic and therefore, it is subjected to casting [11,12]. These components are known as pre-machined cast-on [13–15] or overcasted [11,12] abutments/cylinders. These cylinders were developed to minimize casting distortion at the strap of the components [11,12], in an attempt to enhance the fit and passive of implant-supported frameworks. The better framework fit, the lower the load on the set, ensuring maximum effectiveness of the component [14]. Despite the cylinder's type to be an important factor for the stability of the system, according to authors' best knowledge there is no study that evaluated the influence of mechanical load conditions on the misfit and strain of full-arch implant-supported prosthesis fabricated with different

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prosthetic cylinders (entirely calcinable or used for overcasting). Most of the studies only assess single-unit restorations. The biomechanical behavior of single- and multi-unit implant-supported prosthesis differs [16,17]. In addition, the number of completely edentulous patients seeking full-arch restorations has increased worldwide [18–20].

In addition to the passive fit, the location and magnitude of occlusal forces affect the quality and amount of stress transmitted to the system [21]. During masticatory activity, forces act in different directions on the implants and are transmitted to the peri-implant bone. *In vitro* studies have performed mechanical cycling to simulate masticatory function and to evaluate the interaction between detorque, stress and misfit [11,12,15]. Mechanical loading is an important methodology for evaluating biomechanical behavior and longevity of the implant-supported system since it may change the properties and characteristics of the materials [22]. This procedure is fundamental to assist professionals in choosing the material to be used clinically, not only based on a cost-effective approach, but mainly regarding the biomechanical performance of such restorations. *In vivo* studies are very time-consuming and sometimes impossible to be performed owing to ethical problems.

Regarding the influence of manufacturing procedures in obtaining passive frameworks and stress transmission to the osseointegrated system, the aim of this study was to evaluate the influence of casting and masticatory simulation on the marginal misfit and strain in multiple implant-supported prostheses manufactured with two cylinder types (calcinable and overcasted). Additionally, we investigated the correlation between misfit and strain generated in multiple implant-support prostheses. The hypotheses tested were: (1) calcinable cylinders present higher misfit than overcasted ones, and (2) calcinable cylinders present higher strain than overcasted ones.

2. Materials and methods

2.1. Prosthetic framework and model fabrication

A steel master model was manufactured according to each clinical situation evaluated in this study: a partially edentulous area to be rehabilitated with a three-unit screw retained fixed dental prosthesis (FDP) of lower first pre-molar to first molar retained by two implants; and a completely-edentulous area to be rehabilitated with a mandibular screw retained full-arch fixed dental prosthesis (FAFDP), retained by five implants. Dental implant abutment analogs with platform diameter of 4.1 mm (Mini-Abutment Analogs, SIN — Sistema de Implante, Sao Paulo, Sao Paulo, Brazil) were fixed to it using transversal screws and designated as Pillar A and Pillar B (FDP), and Pillars A, B, C, D, E (FAFDP), from right to left (Fig. 1).

Calcinable or overcasted abutment cylinders (SIN — Sistema de Implante, Sao Paulo, Sao Paulo, Brazil) were screwed on steel master model and master frameworks were waxed with a low-shrinkage acrylic resin (Duralay II — Reliance Dental Mfg. Co., Chicago, USA). The FDPs were fabricated with 3.5×4.0-mm connector cross-section and the FAFDP with 5-mm bar cross-section and 15-mm bilateral cantilever extension.

The master frameworks were impressed (Flexitime Easy Putty Correct Flow — Heraeus-Kulzer, Hanau, Germany) and duplicated to obtain forty frameworks that were divided in four groups ($n = 10$) according to the cylinder type (calcinable or overcasted) and prosthesis design (FDP or FAFDP). The fit of the waxed frameworks was evaluated on the master model by single-screw test [12,23–24]. All waxed frameworks were sectioned and reunited with a low-shrinkage acrylic resin to verify the full fit on the master model according to single-screw test [12].

The steel master model was impressed with silicone (Zeta Labor; Zhermack, São Paulo, SP, Brazil) to obtain a silicone matrix for stone cast models fabrication with the same dimensions of master model. One stone cast model with the same dimensions as the master model was obtained for each prosthesis type using modified conical dental implant analogs (Fig. 2) from master waxing framework. The master waxed frameworks were screwed to the modified dental implant analogs (Fig. 2), the set was positioned perpendicular to the ground, with a parallelometer, and 9 mm of the analog stem was included in a silicone matrix filled with type IV dental stone cast (Durone IV — Dentsply, New York, USA) (Fig. 3). Type IV dental stone cast was manipulated according to manufacturer recommendation (19 mL of water and 100 g of powder for 30 s in vaccum). The models were acquired before framework casting in order to verify the misfit related to the casting procedures. Afterwards, the models were fabricated, the frameworks were invested (Gilvest HS — BK Giulini, Ludwigshafen, Germany), and casted or overcasted in CoCr alloy (Starloy C — Degudent, Dentsply, Hanau-Wolfgang, Germany) using the lost-wax casting technique. No section or welding procedure was applied to evaluate the effect of the prosthetic cylinder in obtaining of frameworks with one-piece casting technique. After casting, the frameworks were blasted with 100 μm aluminum oxide particles at 0.55 MPa pressure followed by finishing and polishing with tungsten carbide drills at low speed. These procedures are required to remove the remaining investing material adhered to the surface of the casted framework. The metallic strap region of the cylinder was protected from such procedure to not compromise the fit of the cylinder. Therefore, these procedures neither affect the masticatory simulation nor the misfit levels of the frameworks when subjected to mechanical cycles.

2.2. Marginal misfit evaluation

The marginal misfit evaluations were performed according to the single-screw test [12,23,24], which proposes the marginal misfit reading of the loop presented while the screw of the opposite pillar is tightened.

The pillar A prosthetic screws of the FDP and FAFDP samples were tightened with 10 N cm torque using a 0.1 N cm precision digital torque meter (Torque Meter TQ-8800 — Lutron, Taipei, Taiwan) and then the misfit measurements were taken on the buccal and lingual gap sides

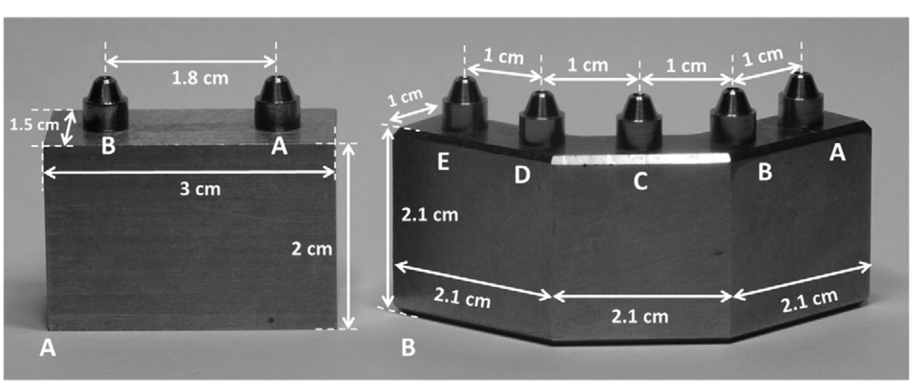

Fig. 1. Steel master model — FDP (A), FAFDP (B).