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ORIGINAL ARTICLE

Influence of the casting technique and dynamic loading on screw detorque and misfit of single unit implant-supported prostheses

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Abstract

Objective. This study aimed to evaluate the influence of the casting procedure and cyclic loading of prosthetic frameworks on detorque of prosthetic screws and marginal misfit of single unit implant-supported prostheses. ***Materials and methods.*** Twenty specimens were obtained, each one consisting of a set of an implant (external hexagon 3.75 × 13 mm – Branemark type), a prosthetic abutment (entirely calcinable or overcasted UCLA) and a prosthetic screw. After the specimens were obtained, the prosthetic screws were tightened with 30 Ncm torque and released 24 h later in order to evaluate initial detorque. The screws were retightened and marginal gaps were assessed. All specimens were submitted to 10^6 loading cycles, performed with 2 Hz frequency and 130 N load. The specimens were re-evaluated for marginal misfit and detorque after the mechanical loading (final marginal misfit/final detorque). The results were submitted to analysis of variance for repeated measurements, followed by Tukey HSD test ($\alpha = 0.05$). ***Results.*** No statistically significant differences were found on detorque values of the prosthetics screws for all groups and intervals evaluated ($p = 0.8922$). The entirely calcinable abutments showed higher initial marginal misfit compared to the overcasted ones ($p = 0.0438$). There was no statistically significant difference on marginal misfit before and after mechanical loading for both groups ($p > 0.05$). ***Conclusions.*** It can be concluded that the overcasted abutments showed lower misfit values when compared to the entirely casted abutments. No difference was observed on detorque values of prosthetic screws. After mechanical loading there was no difference on marginal misfit and detorque between the groups.

Key Words: *dental implant, marginal adaptation, cobalt–chromium alloys*

Introduction

Several studies have sought to improve surgical and prosthetic techniques for implant-supported rehabilitation [1]. Although the affinity between the bone and titanium oxides of alloplastic implants has been demonstrated, studies report biological or mechanical complications, mainly because of the presence of prosthetic misfit [2,3], which could compromise the longevity of these rehabilitations. Therefore, when it comes to the adaptation between prosthesis and implant, a passive relationship is recommended in order to limit the stress transferred to the bone–implant interface. This strategy ensures the maintenance of the osseointegration and the predictability of the treatment [4]. Distortions in metal frameworks can be a consequence of procedures performed during manufacturing, such as casting and investment techniques [5]. Even after being polished, frameworks may not present complete juxtaposition, resulting in a misfit between the metal framework and the implant platform [6].

The passive adaptation of the metal framework is very important, because it reduces stress on the framework, implant and the peri-implant bone [7,8]. The lack of passivity of implant-supported fixed prostheses can lead to complications such as adverse

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reactions of the peri-implant tissue, mechanical failure of the prosthesis, fracture of the system components and loosening screws of the prosthesis [9].

For the manufacture of implant-supported rehabilitations, UCLA-type prosthetic abutments are often used because of their versatility, allowing framework individualization and manufacturing of various types of rehabilitation (single, multiple, screwed or cemented) at a reduced cost. It also allows the possibility of casting not only with precious but also with semi-precious alloys. Despite its versatility, during the casting procedure the platform of the abutment is susceptible to distortions which could compromise adaptation to the platform of the implant, thus creating biomechanical complications for the implant-prosthesis system [10]. Aiming to minimize changes at the bottom of UCLA components, which may result from the framework casting procedure, manufacturers have developed abutments for overcasting. In an overcasted abutment, the bottom of the abutment, which is in contact with the platform of the implant, is pre-machined in metal by the manufacturer and only the cylinder is calcinable, while the conventional UCLA is entirely made of plastic, thus entirely calcinable. The overcasted abutments initially were idealized for overcasting with precious metals, but currently are also machined and casted in non-precious alloys, such as Co-Cr and Ni-Cr [4].

Instability and loosening of prosthetic screws are frequently reported in rehabilitative therapy with dental implants [7,11]. Besides the lack of passivity, the literature suggests [12] that other factors can influence the stability of the prosthetic screws, such as insufficient torque [13,14], settling and relaxing of the screw [15,16] and differences in shape and material of the screw [14,15].

The process of loosening of retention screws occurs in two stages. First, external forces, such as masticatory loading, cause sliding of the screw threads and consequent reduction of the accumulated stress in the screw, known as pre-load. The second stage of screw loosening involves the reductions of the pre-load to a critical level, capable of causing damage to the screwed bolt [17].

When a screw loosens, it is unpleasant for the patient and expensive for the professional [18]. Although retorque is a common practice during the manufacture and clinical follow-ups of the prosthesis, its achievement may indicate a gradual reduction in the removal torque and consequent instability of the system [18,19]. Screw loosening itself is not a complication for the screw; the actual problem is that this loosening can result in serious problems for other components of the system [20], maybe resulting in fracture of the retaining screw, abutment and/or implant; overload and biological complications [18,19]. An overload on the screws can lead to eventual loosening. Related to treatment success and load on the system, there is consensus that the location and magnitude of occlusal forces affect the quantity and quality of the stress transmitted to the system components [21,22]. The excessive load on implants is dependent on the location in the dental arch, the physiological characteristics of the patient [21], type of material selected for the occlusal surface of the prosthesis and factors related to stress distribution [23,24].

Therefore, if the tension that holds components together decreases beyond a critical level, the stability of the joint can be compromised and fail clinically [25]. External forces cause sliding of screw threads and vibrations capable of resulting in detorque [26]. In *in vitro* studies, such a situation may be simulated by mechanical loading and comparison between the torque and detorque values, as a measurement of the pre-load remaining in the retention screw [27].

Passive adaptation in prosthetic frameworks is extremely important in the maintenance of osseointegration of dental implants, as is the effect of framework manufacturing techniques on the misfit and stability of rehabilitations. Therefore, the evaluation of the misfit and detorque has become relevant and current. This study thus has aimed to evaluate the influence of the manufacturing method of prosthesis components (casting and overcasting) and mechanical cycles (130 N and 2 Hz) in detorque of the prosthetic screw and marginal misfit in single unit implant-supported prostheses.

Materials and methods

Twenty specimens were obtained composed of a set of an implant, a prosthetic abutment and a prosthetic screw (Conexão Sistema de Prótese, São Paulo, Brazil). The implants (external hexagon 3.75×13 mm – Branemark type) were placed perpendicular to the ground with the help of the delineator. They also were included in chemically-activated acrylic resin (Vipi Mold – Vipi Dent, Pirassununga, Brazil) in order to obtain a stable platform for fixation of the specimens during torque performance, mechanical cycling and misfit measurements procedures. A plaster index was made, containing an implant analog with a 4.1 mm platform and external hexagon connection, over which the entirely calcinable and overcasted prosthetic components were waxed with standardized dimensions, using a laboratory silicone matrix (Zetalabor – Zhermack, Rovigo, Italy). The UCLAs were included in investment for casting with alternative alloys (Gilvest HS – BK Giulini, Ludwigshafen, Germany) and casted or overcasted in Co-Cr alloy (Starloy C – Degudent, Dentsply, Hanau-Wolfgang, Germany). After the casting, the sets were cleaned with aluminum oxide with 100 μm particles at a pressure of 0.55 MPa. All frameworks were finished and polished except for the implant contacting area of the components.

Table I. Mean values of loosening (Ncm) according to the groups and time intervals.

UCLA	Times	
	Initial	Final
Calcinable	14.91 (2.99)^{Aa}	16.24 (5.87)^{Aa}
Overcasted	17.01 (4.90)^{Aa}	13.91 (7.65)^{Aa}

Means followed by same letters (capital, column; minor, line) indicate no statistical difference according to ANOVA; F test (p = 0.8922).

All abutments and prosthetics screws were randomly distributed between implants after obtaining the casted components, forming sets containing one prosthetic abutment and one screw, for a total of 10 sets with overcasted components and 10 with entirely calcinable casted components.

The screws were submitted to 30 Ncm torque through a digital torque meter (Torque Meter TQ-8800 – Lutron, Taipei, Taiwan) and loosened after 24 h for the measurement of initial detorque. After obtaining the initial values of detorque, the screws were tightened again, with 30 Ncm torque.

The screwed sets were submitted to the evaluation of the marginal misfit between prosthetic components and implant platform using a measuring microscope with an accuracy of 1.0 μm and increase of 120-times (VMM-100-BT – Walter UHL, Asslar, Germany). The microscope was equipped with a digital camera (KC-512NT – Kodo BR Eletronics Ltda, São Paulo, Brazil) and analyzer unit (QC 220-HH Quadra-Check 200 – Metronics Inc., Bedford, MA). The observations were made by a calibrated examiner (kappa = 0.92) in four sides of the implant/UCLA set, with rotations of 90°. The marginal misfit was evaluated before and after the cyclic loading and was defined as the average value obtained among the four measurements of each set.

After initial misfit measurements, the sets were submitted to the process of cyclic loading, in which specimens were immersed in artificial saliva (1.5 mM Ca, 3.0 mM P, 20.0 mM $NaHCO_3$, pH 7.0) [28] at room temperature (25°C) and exposed to 10^6 mechanical cycles, performed with 2 Hz frequency (Mechanical Fatigue Simulator, ERIOS, model ER – 11000 – Plus, São Paulo, Brazil) and a compressive load of 130 N [29]. The mechanical cycles were performed to simulate the masticatory cycles. For the present study the specimens were fixated to the equipment, so they did not move or dislocate during loading procedures. Loading was performed by a series of pistons that contacted the specimens at all times. Therefore, there was no impact load upon the specimens. The pistons were positioned in the center of the oclusal table of the frameworks, which was parallel to the long axis of the implant. The point of load application was constant. The observation of the marginal misfit was performed again after cyclic loading, followed by the measurement of final detorque value.

All data obtained were submitted to analysis of variance (ANOVA) for repeated measurements and Tukey's HSD test (α = 0.05 – SAS version 9.1, The SAS Institute, Cary, NC).

Table II. Mean values of marginal misfit (μm) according to groups and time intervals.

UCLA	Times		p-value
	Initial	Final	
Calcinable	39 (15.25)^{Aa}	34.38 (12.78)^{Aa}	0.1028
Overcasted	24.05 (7.59)^{Ba}	26.63 (9.56)^{Aa}	0.3410
p-value	0.0432	0.27	

Means followed by different letters (capital, column; minor, line) differ statistically according to ANOVA/Tukey tests (α = 0.05).

Results

As can be seen in Table I, significant differences were not observed in detorque of the prosthetic screws for casted and overcasted abutment groups (p = 0.8922), according to the ANOVA. There were no statistically differences in detorque before and after the mechanical loading for all groups evaluated (p = 0.8922), according to the ANOVA. The average values of initial and final detorque (Ncm) of the frameworks are shown in Table I.

Table II shows the mean values of initial and final marginal misfit (μm) of the frameworks. The statistical analysis showed significant differences between the groups according to ANOVA/Tukey tests. Higher marginal misfit was presented by the casted abutments on the initial measurements (p = 0.0438). No difference was observed between casted and overcasted abutments after cyclic loading (p = 0.27). However, no statistically significant difference between initial and final misfit, before and after the mechanical loading, was observed on the entirely calcinable (p = 0.1028) and the overcasted (p = 0.3410) groups.

Discussion

In this study, in frameworks of single-unit prostheses, the overcasted abutments showed better fit than the entirely calcinable ones before mechanical cycles. It can be observed that the marginal gap between the abutment and the implant was smaller in the overcasted specimens (Figures 1a and b) than in the entirely casted (Figures 1c and d). The lowest rates of misfit showed by the overcasted abutments can be explained by the presence of a pre-machined base for juxtaposition to the implant platform. The other

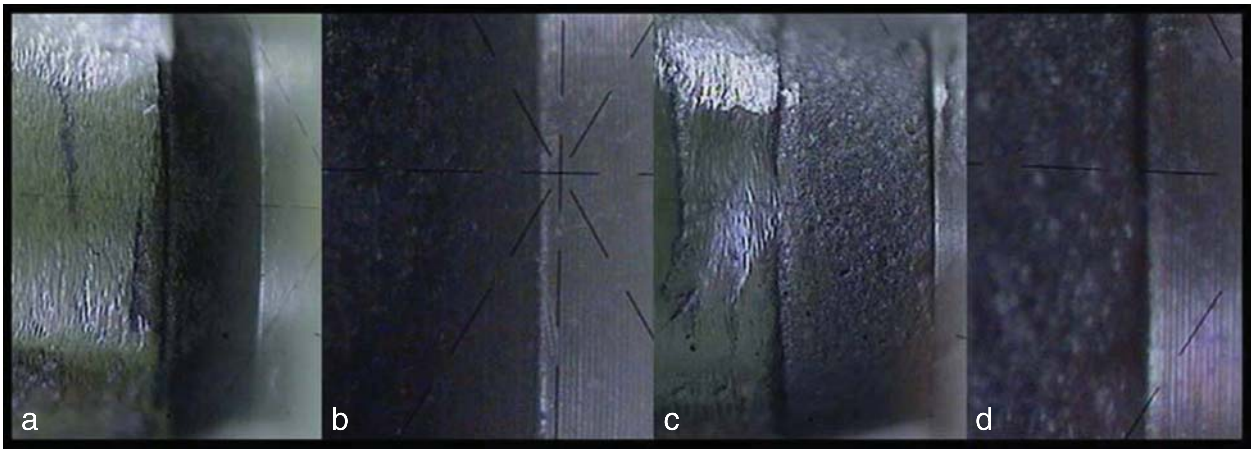

Figure 1. Implant/abutment interface of the overcasted (a) and entirely calcinable (c) specimens. Images (b) and (d) are 120 × magnified.

abutments, by being entirely casted, are subjected to distortions as a result of the casting process.

Most of the distortion caused by casting occurs due to the volume change of materials: plaster, waxes, investment, casting metals, impression material and application of the esthetic coverage [2,30]. The type of alloy used to manufacture the prosthetic frameworks is another factor that can interfere with obtaining a satisfactory adaptation [31]. It has been demonstrated that frameworks of implant-supported prostheses, when casted in alternative alloys (Co-Cr and Ni-Cr-Ti), show higher marginal misfit than frameworks casted in commercially pure titanium (cp titanium) [1]. Such performance may be explained by the difference in the composition of these alloys and by their different melting temperatures (Co-Cr alloy, 1370°C; Ni-Cr-Ti alloy, 1329°C; and cp titanium, 1700°C) [32]. Differences in the composition of alloys generate different physical properties such as deformation, rigidity, hardness, young's moduli and melting temperature. Different melting temperatures of the casting metals generate different cooling speed, which might be related to the amount of contraction of the material used to cast the frameworks. Thus, these factors might influence in levels of marginal misfit of casted piece.

Regardless of the type of abutment used (UCLA or intermediary) and of the type of prostheses (multiple or unitary), higher marginal misfit will be obtained in entirely calcinable frameworks. In single-unit rehabilitations, the benefit provided by the overcasting procedure is more evident because of the presence of the anti-rotational system inside the abutment. In the present study, visual evaluation of the anti-rotational polygon demonstrated that, after casting, the pre-machined abutments (overcasted specimens) presented higher quality edges. The anti-rotational polygon, as well as the overall abutment interface were presented to be smoother and porosity free (Figure 2). The inaccurate reproduction of angles and edges of the anti-rotational polygon during conventional casting procedures may compromise the settlement and stability of the single-unit framework (Figure 2). As such, the presence of a metal pre-machined anti-rotational polygon would not only improve the fit of the framework but also reduce the chances of biomechanical failure. Nonetheless, one-piece casted frameworks that do not present an

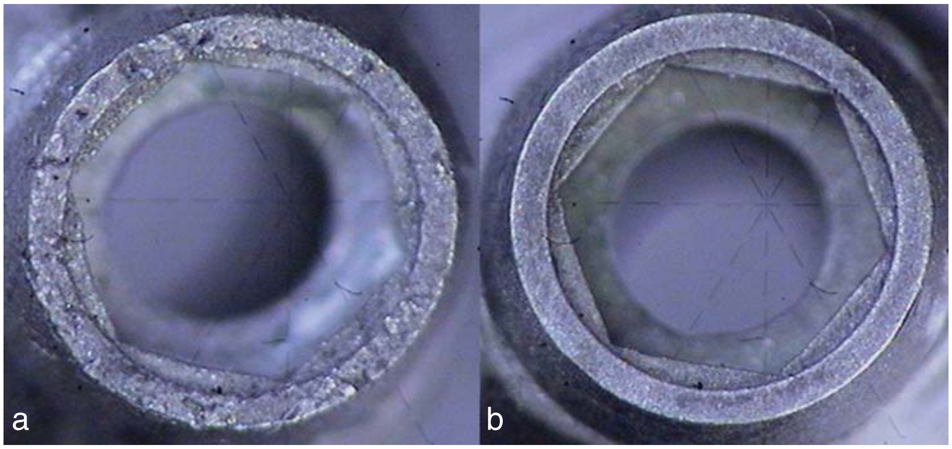

Figure 2. Visual evaluation of the quality of the reproduction of the anti-rotational polygon of the abutment: entirely calcinable (a) and overcasted (b).

anti-rotational system also present an inadequate fit between the calcinable UCLA and the platform of the implant [33]. Such behavior also was observed between intermediary abutments and the calcinable copings of multiple implant-supported prostheses [34].

Although the level of clinically acceptable marginal misfit is still very controversial, values between 10–150 μm [7,35] are considered suitable. However, the higher the marginal misfit of implant-supported prostheses, the higher is the chance that these prostheses will present biomechanical problems.

The presence of a higher misfit on entirely casted single-tooth implant prostheses indicates lower contact between the implant and the abutment [33]. The reduced contact presented by entirely casted abutments has implications such as screw loosening [30,36,37] due to considerable reduction of the friction between the components or screw fracture [36,37]. In single-unit implant-supported restorations, maximum contact between the implant–abutment interface is necessary for the reduction of oblique loading on both the abutment and the retention screw, ensuring maximum efficacy of system components, since the stability of the screw is an important factor for the success of unitary prostheses [33]. In addition, the high temperatures to which the frameworks are subjected during the casting process result in changes in the mechanical performance and structural properties of surfaces in contact during the adaptation of the screw threads with implant osseointegrated. This causes changes in values of frictional resistance in application of torque [38].

Nonetheless, detorque values of prosthetic screws of conventionally casted or overcasted single-unit frameworks do not show any difference when evaluated before or after simulation of clinical use, which suggests that prosthetic screws of both casted and overcasted frameworks present similar mechanical behavior. The measurement of screw detorque verifies the real values of force absorbed by prosthetic screws after the initial torque and also evaluates the effect of a compressive load (masticatory simulation) in the torque maintenance of these screws. Therefore, the detorque force was evaluated twice: 24 h after initial tightening of the screws (initial detorque) and after loading cycles (final detorque). Loading parameters (130 N and 2 Hz) were estimated from the assumption that an individual performs three episodes of masticatory movements per day, each one 15 min in duration at a frequency of 60 cycles per minute, which is equivalent to 2700 cycles per day and ~ 10^6 cycles per year [29,39].

Marginal misfit of single-unit implant-supported frameworks does not affect the detorque of prosthetic screws. Initially, it would be expected that loading could result in a decrease of pre-load originated from the initial torque. The incidence of external masticatory forces would result in sliding of the screw threads and consequent reduction of the accumulated pre-load tension in the screw [17]. However, the maintenance of the detorque values after loading suggests that higher values of marginal misfit do not necessarily result in reduced pre-load of the prosthetic screws, which would compromise the stability of the frameworks [40]. Nonetheless, these results could have been influenced by the type of load applied over the frameworks, since the mechanical cycling was performed only with axial loading. Oblique forces applied over implants are more deleterious than axial forces. However, the objective of this study was to assess the behavior of prosthetic abutments alone. Marginal misfit is already an unfavorable situation under axial loading; therefore, with oblique loading this behavior is expected to be the same or even exacerbated. Thus, regardless of the type of load that was applied, the conclusion on which abutment type presents a more favorable biomechanical behavior is still the same. Nonetheless, additional studies are in need to evaluate the effect of oblique loading on marginal misfit of prostheses and detorque of prosthetics screws.

Based on the results obtained by comparing overcasted and casting UCLA abutments for implant-supported single-unit prostheses, it can be concluded that overcasted UCLA abutments present lower marginal misfit than entirely calcinable ones, but no difference has been observed on the detorque of the screws retaining these abutments. After the simulation of clinical performance, by means of mechanical loading, there is no difference on screw detorque and marginal fit of these prostheses.

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