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Survival Analysis and Torque Loosening of Experimental Screw After Mechanical Performance for Micro Conical Abutment

Análisis de Supervivencia y Apriete del Tornillo Experimental Tras Funcionamiento Mecánico para Pilar Microcónico

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ABSTRACT: The most common failure in implantology are due to mechanical instability. Torque loosening or fracture of the screws are the most frequent complications. Furthermore, the fractured screw retrieval is complicated and time-consuming. So, modifications in the design of implant systems are justifiable to offer a greater degree of biomechanical stability. Thus, the present study proposes to evaluate an experimental geometry for abutment screw regarding failure probability and torque loss. Twenty implant/abutments sets (e-fix, A.S. Technology – Titanium Fix) were divided into the following groups (n=10 in each group): (1) Conventional screw (Screw neck ø 1.5 mm) and (2) Experimental screw (screw neck constricted ø 1.2 mm). The abutments were tightened with a controlled torque meter device following the manufacturer's recommendations. Mechanical cycling was carried out with a load of 50 N.cm during 5 x 10^6 cycles with a frequency of 2 Hz at a temperature of 37 °C (ISO 14801). A digital torque meter was used to measure the reverse torque values of the prosthetic screw and the micro abutment screw, before and after loading. Data were statistically analyzed by One-way Anova and Tukey test (95 %). The results of the mean values of torque loss of the micro abutment screw were 58.44 % for the control group and 55.31 % for the experimental group and the mean torque loss for the prosthetic screw was 53.3 % and 61.3 % of the conventional and experimental groups, respectively. The survival probability was 100 % for both screw groups. It was concluded that experimental screw showed a similar behavior to conventional screws, showing similar reliability after fatigue life testing.

KEY WORDS: dental implants, fixed prosthesis, dental materials.

INTRODUCTION

The goal of dentistry is to restore the patient's function and health. Dental implant is a treatment option that includes important advantages as patient comfort, aesthetics, absence of damage to adjacent teeth in addition to a high long-term success rate, when compared to traditional treatments like fixed dental prostheses restorations, partial or complete removable dentures (Wöhrle, 2003; Funato *et al*., 2007; Kotsovilis *et al*., 2009; Wittneben *et al*., 2014; Von Stein-Lausniz *et al*., 2019; Omori *et al*., 2020). Despite the implant survival rates, there is still risk of technical and biological complications, both in the surgical stage and in the prosthetic step (Wittneben *et al*.). Regarding the technical complications, torque loosening or fractures of the abutment screws are the most common. The prevalence of torque loosening of the screw is higher for external hexagon implant systems, both angle and straight abutments (Fu *et al*., 2012; Coelho *et al*., 2014; Wittneben *et al*.; Katsavochristou & Koumoulis, 2019; Omori *et al*.).

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Studies report that complication incidences rate of screw fracture is around 0.5 % to 8 %. These failures are usually due to the overload, which can occur due to long axis implant angulation relative to the occlusal plane, in addition to horizontal offset, vertical offset (crown-to-implant ratio), and parafunctional habits, such as bruxism, or excessive torque applied (Coelho *et al*.; Imam *et al*., 2014; Liaw *et al*., 2015; Oh & Barnes, 2016; Flanagan, 2016; Goodacre *et al*., 2018).

A literature review by Goodacre *et al*. reported that among prosthetic complications, the abutment screws loosening was not a common occurrence, but it was the most reported complication, and was observed in 262 of the 7,648 analyzed crowns (3 %) (screwed and cemented single crowns) (Kourtis *et al*., 2017; Goodacre *et al*.). This occurrence was related to screw designs and lack of defined methods for tightening the screws (Goodacre *et al*.). Strategic improvements need to be developed for old implants that now have prosthetic complications (Kourtis *et al*.).

Although the abutment screw fracture is not most recurrent mechanical problem (Eckert & Wollan, 1998), it is important to highlight that when it occurs, there is great difficulty in removal, which can lead to loss of the implant (Satwalekar *et al*., 2013; Schmage *et al*., 2014; Shah & Lee, 2016). The ideal geometry of the screw should provide a favorable design for the removal of the broken parts (Melo-Filho *et al*., 2019). In this way, the ideal geometry of the abutment screw containing a thinner portion in the screw's neck, can direct the fracture to a more external region, easier to remove (Siamos *et al*., 2002; Melo-Filho *et al*.). Research on torque mantainance during fatigue and survival rates are needed whenever the design is modified.

Therefore, the aim of this study was to evaluate an experimental geometry for a micro-pillar screw regarding to failure probability and the torque maintenance after fatigue test. The tradiotional screw was used as control.

MATERIAL AND METHOD

This study was conducted according to the international standard fatigue test (ISO 14801:2016) for endosseous dental implants in vitro (International Organization of Standardization, 2016).

Specimen Preparation. Twenty cylinders were made with a 30° inclination, in polyurethane resin (F16, AXSON, Brazil), with an elastic modulus equal to 3.6 GPa (Melo-Filho *et al*.). This cylinder was used as bone simulation. So, the alveolus of each implant (n = 20) was milled with the long axis perpendicular to the horizontal plane using the cutter indicated by the manufacturer, according to the implant diameter. Then, the external hexagon implants (4.0 x 13 mm) were installed (40 N.cm), leaving 3 mm of implant threads exposed (ISO 14801:2016).

Mini-abutments (2.5 x 4.0 mm) were installed (32 N.cm) on the implants; half of them received their respective screw (e-fix, A.S. Technology - Titanium Fix, São José dos Campos, SP, Brazil), and the other half received the experimental screws (e-fix, A.S. Technology - Titanium Fix, São José dos Campos, SP, Brazil) previously validated to the stress concentration and fracture load (Melo-Filho *et al*.). This group was designated experimental because the abutment screw had a 1.20 mm constriction in the smooth part of the neck to direct the fracture above the region of the threads.

A simplified crown (A.S. Technology - Titanium Fix, São José dos Campos, SP, Brazil), which replaced the crowns, were made of stainless steel according to the parameters described in ISO 14801:2016 (Fig. 1). The devices were designed and machined, to measure, for the micro pillar used to be perfectly coupled, not allowing movement and without anti-rotational system (Fig. 2A).

The design of the simplified crown allowed that the load was applied at a single point of equal area in all samples, thus avoiding uneven stress concentration, as well as premature deformation of the samples.

Then, they were positioned on the abutments, and prosthetic screws were tightened according to the manufacturer’s instructions (15 N.cm) using a digital torque meter, the screws were tightened again to the same initial torque after 10 minutes.

Mechanical Fatigue Aging. The implant/abutment/crown sets were submitted to mechanical fatigue aging (Biocycle, BioPDI, São Carlos, SP, Brazil) immersed in 37°C distilled water using the following parameters: 5x106 cycles, 30° inclination, 50 N load, 2 Hz frequency (Fig. 1) (Khraisat *et al*., 2004; Pereira *et al*., 2016). Cyclic load was applied using a stainless steel rounded-point piston (6 mm diameter) onto the center of the occlusal surface (Fig. 2B).

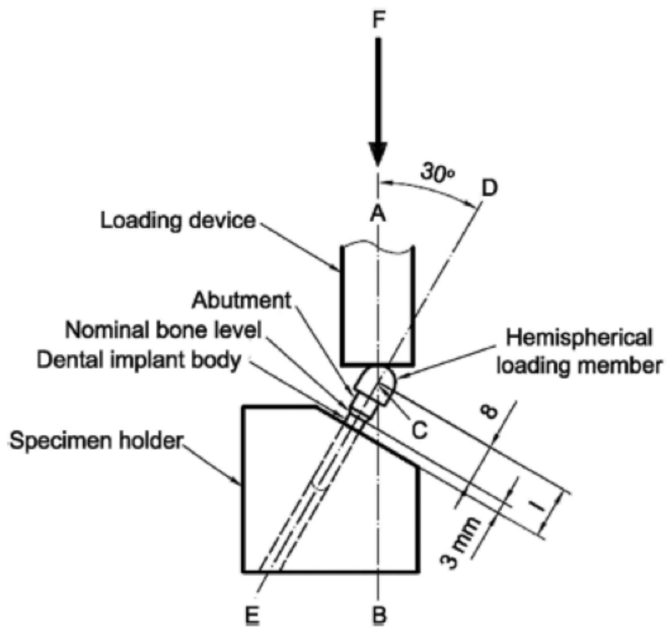

Fig. 1. Schematic of test setup according to The ISO 14801: 2016 recommendations.

A metallic device containing a fitting for the specimen and 3 screws for horizontal tightening used, so that the specimen remains fixed throughout the test. The mechanical aging was interrupted every 5×10^6 cycles to perform a visual and digital evaluation of the specimens to check if there was a fracture or any destabilization of the samples.

Torque Evaluation. Followed the fatigue aging procedure, postload removal torque of the simplified crown and abutment was measured with a digital torque meter. This procedure was performed once on each specimens of each group (n = 10), which showed the values of conventional and modified screws and prosthetic screws.

Data Analysis. Torque evaluation results were submitted to a general linear model for one-way ANOVA repeated measures analysis using the SPSS software (IBM SPSS Statistics). The factor was defined as "screw type" (conventional or experimental). The significance level was 5 % for all tests.

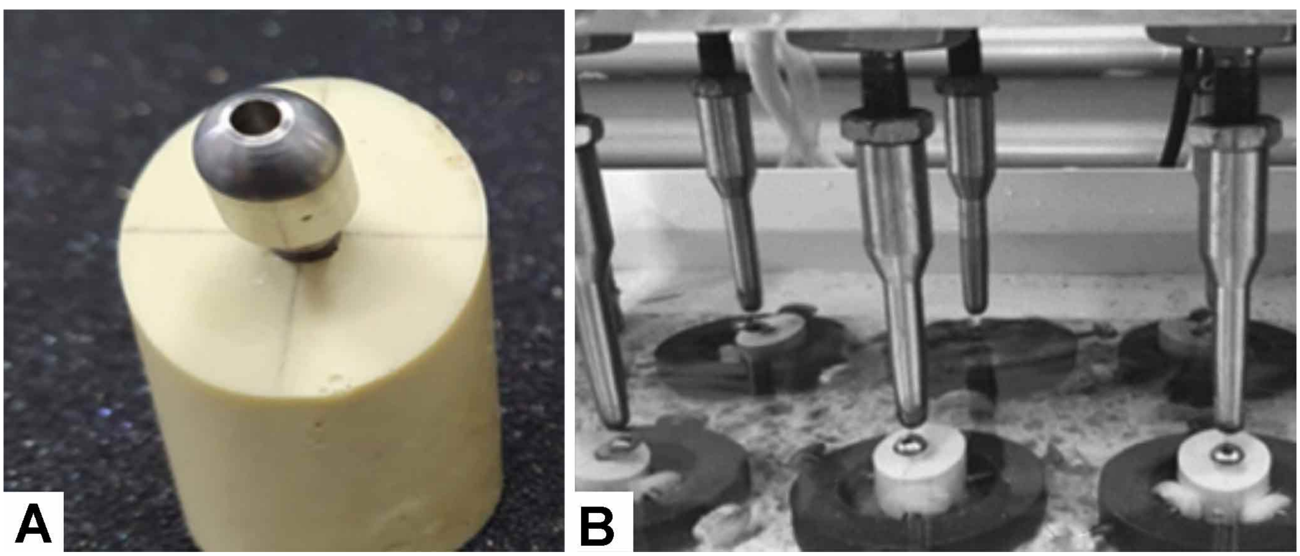

Fig. 2. Specimen used for mechanical fatigue aging tests. A) Sample with micro abutment and crown installed. B) Specimens placed in the fatigue testing machine.

RESULTS

The mean reverse torque values recorded and were analyzed descriptively, and the values are shown in Table I. Levene's test showed that the values are homogeneous ($p > .05$). One-way ANOVA showed no differences statistically significant ($p = .622$ and .534, respectively for mini-abutments and prosthetic screws). Therefore, no difference was observed between the maintenance of the applied torque as a function of the screw geometry (conventional and experimental).

During the mechanical fatigue aging test, no failure was observed, both screws showed 100 % survival after 5 x 106 mechanical cycles at 50 N.

Table I. Mean and Standard Deviation reverse torque (N.cm), and percentage of reverse torque of mini-abutment screws and prosthetic screws.

	Mini-abutment Screw		Prosthetic Screw	
	Mean ± DS	% reverse torque	Mean ± DS	% reverse torque
Control	11.22 ± 4.11	35.06 %	6.11 ± 4.64	40.70 %
Experimental	12.33 ± 5.19	38.53 %	4.77 ± 4.23	31.80 %

DISCUSSION

According to literature, the screw was designed to be the "weakest link" that will fail before damage to the prosthesis or implant occurs (Doolabh *et al*., 2014). The technical complications are associated to presented parafunctional habits and non-axial loads, bring on a higher risk of prosthesis failure, as well as a higher risk for torque loosening of the screw, or even the screw fracture (Theoharidou *et al*., 2008; Jung *et al*., 2012). The material's properties of screw fabrication and the inadequate torque of the screw, such as low mechanical strength and fatigue, are also important risk factors associated with loosening or fracturing of the screws (Freitas *et al*., 2010).

The most current abutment screw torque loosening longitudinal studies ranges between 7 % and 11 % (Katsavochristou & Koumoulis). And five factors were identified as being important in relation to the loss of torque of the screws: the type of connection, the design and material of the screw, the type of prosthetic abutment, the settling effect, and internal loads (Pardal-Peláez & Montero, 2017).

According to previous studies (Peixoto & Almas, 2016; Melo-Filho *et al*.), the screw stress peaks were concentrated in the first threads of the prosthetic screw, due to the high flexural movement of the screw when subjected to preload or during mastication. This shows that the correct screw geometry and the combination of materials can be important for the stress distribution in the screw (Peixoto *et al*., 2016; Melo-Filho *et al*.).

Abutment screw fracture is the problem that causes a clinical complication that is exacerbated by the difficulty in removing the pieces of the implant screw, although there are several methods for removal (Kim *et al*., 2012). Based on this and on several reports related to prosthetic complications in implantology, changes in the geometry of implant systems became justifiable so that it would provide greater biomechanical stability between its connections (Vinhas *et al*., 2020).

A previous study by Melo-Filho *et al*. tested that an experimental prosthetic geometry, the same used in this study, with a 0.3 mm constriction in the diameter of the neck region, which was an important factor in the stability, fracture strength and stress distribution, favorably altering the behavior of the entire system (Melo-Filho *et al*.). However, the absence of cyclic loading on the longevity and torque maintenance was a limitation of that study. Therefore, the present study performed fatigue and the measurement of torque loss, and the performance was no statistical significant of the different screws.

The fatigue behavior is dependent of several aspects, and can be conducted of so many ways to cause the mechanical degradation. Accelerated life testing (Step-stress – SSALT), Staircase, constant stress fatigue test are examples of methods to analyze the life prediction and/or survival probabilities of dental materials, and should selected according to aim of the study and the capacity of the used fatigue equipment (Bonfante & Coelho, 2016). The major limitation of the present study is the fatigue method used, which can represent that the real fatigue limit was not reached, since there was no fracture even after 5×10^6 cycles. Despite the physiological range used to mechanical aging, the used load probably overestimated the fatigue performance. There are no consensus about the testing parameters, but Ayllón *et al*. (2014) showed according the theoretical model that the fatigue limit of dental implants is around 120 N.

Thus, the results indicate that the experimental geometry can be an alternative to minimize possible failures because the screw geometry did not affect the torque loosening of the screw and other failures, corroborating with others researches (Arnetzl *et al*., 2016; Mattheos *et al*., 2016; Goodacre *et al*.; Melo-Filho *et al*.). These studies observed that the geometry of the screw favors the screw stability and generate a smaller number of failures, for example, a higher value of reverse torque and/or a more favorable failure (Arnetzl *et al*.; Mattheos *et al*.; Goodacre *et al*.; Melo-Filho *et al*.).

According to the literature, the more apical the screw fracture the greater the difficulty in removing the remnant located inside the dental implant (Mizumoto *et al*., 2018; Malpartida-Carrillo *et al*., 2020). Thus, the proposed geometry of the experimental screw is a good alternative to avoid fracture in regions of difficult access and removal (Melo-Filho *et al*.).

CONCLUSIONS

Considering the *in vitro* study limitations, it was possible to conclude that the experimental screw showed a behavior under fatigue and torque maintanance similar to the traditional one and should be used alike.

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PIGNATARO, R. R. G.; DE MATOS, J. D. M.; PINTO, Í. L. R.; SAMICO, R. P.; BOTTINO, M. A.; RAMOS, N. C.; MARINHO, R. M. M. Análisis de supervivencia y apriete del tornillo experimental tras funcionamiento mecánico para pilar microcónico.*Int. J. Odontostomat., 16(1)*:27-32, 2022.

RESUMEN: En implantología las fallas más habituales se deben a la inestabilidad mecánica. El aflojamiento del torque o la fractura de los tornillos son las complicaciones más frecuentes. Además, la recuperación del tornillo fracturado es complicada y requiere mucho tiempo. Por tanto, las modificaciones en el diseño de los sistemas de implantes están justificados para ofrecer un mayor grado de estabilidad biomecánica. Por lo tanto, el presente estudio propone evaluar una geometría experimental para tornillo de pilar en cuanto a probabilidad de falla y pérdida de torque. Se dividieron veinte conjuntos de implantes / pilares (e-fix, AS Technology - Titanium Fix) en los siguientes grupos (n = 10 en cada grupo): (1) Tornillo convencional (cuello de tornillo ø 1,5 mm) y (2) Tornillo experimental (cuello de rosca estrechado ø 1,2 mm). Los pilares se apretaron con un dispositivo medidor de torque controlado siguiendo las recomendaciones del fabricante. El ciclo mecánico se realizó con una carga de 50 N.cm durante 5×10^6 ciclos con una frecuencia de 2 Hz a una temperatura de 37 ° C (ISO 14801). Se utilizó un medidor de torque digital para medir los valores de torque inverso del tornillo protésico y el tornillo de micro pilar, antes y después de la carga. Los datos se analizaron estadísticamente mediante la prueba One-way Anova y Tukey (95 %). Los resultados de los valores medios de pérdida de torque del micro tornillo de pilar fueron 58,44 % para el grupo de control y 55,31 % para el grupo experimental y la pérdida de torque media para el tornillo protésico fue 53,3 % y 61,3 % de los grupos convencional y experimental, respectivamente. La probabilidad de supervivencia fue del 100 % para ambos grupos de tornillos. Se concluyó que el tornillo experimental mostró un comportamiento similar a los tornillos convencionales, mostrando una fiabilidad similar después de la prueba de vida a fatiga.

PALABRAS CLAVE: implantes dentales, prótesis fija, materiales dentales.

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