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Original article

Effect of unilateral misfit on preload of retention screws of implant-supported prostheses submitted to mechanical cycling

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Abstract

Purpose: The aim of this study was to evaluate the effect of different levels of unilateral angular misfit on preload maintenance of retention screws of single implant-supported prostheses submitted to mechanical cycling.

Materials and methods: Premachined UCLA abutments were cast with cobalt–chromium alloy to obtain 48 crowns divided into four groups ($n = 12$). The crowns presented no misfit in Group A (control group) and unilateral misfits of 50 μm, 100 μm and 200 μm in the groups B, C and D, respectively. The crowns were attached to external hexagon implants with a titanium retention screw with torque of 30 N/cm. Oblique loading of 130 N at 2 Hz was applied on each replica, totalizing 5×10^4 and 1×10^6 cycles. Detorque values were measured initially and after each cycling period. Data were evaluated by analysis of variance and Tukey's HSD test ($p < 0.05$).

Results: All groups presented reduced initial detorque values ($p < 0.05$) in comparison to the insertion torque (30 ± 0.5 N/cm) and Group A (25.18 N/cm) exhibited the lowest reduction. After mechanical cycling, all groups presented detorque values from 19.5 N/cm to 22.38 N/cm and the mechanical cycling did not statistically influence the detorque values regardless the misfit level of the replicas.

Conclusion: The unilateral misfit influenced the preload maintenance only before mechanical cycling. The mechanical cycling did not influence the torque reduction.

Keywords: Implant-supported prosthesis; Dental implant; Misfit; Preload; Mechanical cycling

1. Introduction

Passive fit between prosthesis and implant is important to minimize the stress generated between these structures and allow stress transferring to bone tissue surrounding the implant [1,2]. When passive fit is not observed, stress may generate ischemia and microfractures in peri-implant bone associated to other factors that may jeopardize the success and longevity of the implant [3,4]. In addition, excessive dynamic loading results in lateral defects in the bone surrounding the implants [5].

According to a mechanical-prosthetic standpoint, the fracture of a retention screw indicates failure of the superstructure since if proper fit is achieved, the masticatory load does not induce stress exceeding preload [6]. So, the most common long-term failures reported with implant-supported prostheses are loosening and fracture of retention screws [7–9], fracture of abutment screw, and defects and mobility of framework [7]. Although the failures result from multifactorial etiology, the absence of passive fit between prosthesis and implant may be the main cause [8,10].

Thus, many authors [11–13] aimed to achieve the complete fit of prosthetic cylinders to abutments and implants. Although Branemark et al. [14] have suggested that misfit should not exceed 10 μm, the usual technology does not provide this accuracy since the majority of components does not exhibit this level of fit [15,16]. Consequently, prosthesis misfit is a clinical reality but the level of misfit supported without mechanical [4,17] and biological [18,19] failures was not determined.

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The misfit may be classified as vertical, horizontal, angular and rotational [10]. The vertical and rotational misfits are widely discussed since they are related to the most common mechanical problems reported. The horizontal misfit represents the sub and overcontouring between abutment and implant. The angular and vertical misfits are similar since both are characterized by gaps in abutment/implant interface but the angular misfit exhibits an angular gap.

Preload is the stress generated in the screw during tightening in screw joints. Any external force lower than preload increases the stress in the screw while a higher external force, as compression, may lead to screw loosening or fracture [20]. Additionally, the development and maintenance of preload is related to elasticity of screw's material since optimal preload is achieved when the screw is stretched until its yielding limit. Besides, friction between the screw threads results in reduced preload [21].

Scientifically, the resistance of a screw joint is assessed by *in vitro* evaluation of preload maintenance associated to simulation of masticatory function through mechanical cycling [22–27].

The mechanical cycling with different levels of misfit may be used to evaluate the stability of the hexagonal joint. Considering that the screws present the same preload and that detorque value is a indirect measure of remaining preload, any difference in this value after mechanical cycling may be related to misfit between the internal and external dimensions of the hexagons [24].

The cyclic loading on implant-supported prostheses may result in micromovements and fatigue of the metal in screwed prostheses that seem stable. In addition, screw joints on implants that present low preload values exhibit significant higher micromovements at the abutment/implant interface [25]. The authors identified no study that has tested the preload maintenance of retention screws as affected by both angular misfit and mechanical cycling.

Therefore, the aim of this study was to evaluate the effect of different levels of unilateral angular misfit on preload maintenance of retention screws of single implant-supported prostheses submitted to mechanical cycling. The null hypothesis assumed that different levels of misfit and mechanical cycling do no influence preload maintenance of the retention screws.

2. Materials and methods

Forty-eight metallic crowns were fabricated with 48 hexagonal UCLA abutments cast with cobalt–chromium alloy (Co–Cr) (EUCLA 406, SIN - Sistema de Implante, São Paulo, SP, Brazil). Twelve abutments were used as received from the manufacturer while 36 abutments were prepared in a specific machine (GIN-Chan Machinery Co., Ltd., Taipei, Taiwan) to create unilateral angular misfits of 50 μm, 100 μm and 200 μm with accuracy of 8 μm (0.05 ± 0.008 mm, 0.10 ± 0.008 mm, 0.20 ± 0.008 mm).

The plastic sleeves of the abutments were sectioned and coated with autopolymerizing acrylic resin (Duralay; Reliance Dental MFG Company, Worth, IL, USA) in conical shape with 8 mm in height and 8 mm in width [28] with a slice of 30° in the occlusal surface opposite to the misfit. The metallic sphere for loading was positioned on this slice during the mechanical cycling.

All crowns were fabricated according to a silicone matrix (Zetalabor, Zhermack, Badia Polesina, Italy) to present similar dimensions. The patterns were invested with phosphate investment (Flash, CNG Soluções Protéticas Ltda, São Paulo, SP, Brazil) and cast with Co–Cr alloy (StarLoy C, DeguDent GmbH –Rodenbacher Chaussee 4, Wolfgang, Germany).

After casting, the crowns were sandblasted with 60 μm – aluminum oxide (Bio-Art Equipamentos Odontológicos Ltd., São Carlos, SP, Brazil) under 75 lbs of pressure and cleaned with monomer (Jet, Artigos Odontológicos Clássico Ltd., São Paulo, SP, Brazil) followed by water washing and air drying.

The 48 metallic crowns were divided into four groups ($n = 12$) according to the level of fit to the implant: Group A – crowns with complete fit (control group), Group B – crowns with unilateral angular misfit of 50 μm, Group C – crowns with unilateral angular misfit of 100 μm, and Group D – crowns with unilateral angular misfit of 200 μm (Fig. 1). Fig. 2 shows the implant–abutment interface through scanning electronic microscopy (SEM) for all groups.

Forty-eight external hexagon implants in titanium (Ti–6Al–4V) with 3.75 mm in diameter and 15.0 mm in length (Revolution SUR 4015, SIN - Sistema de Implante) were embedded with autopolymerizing acrylic resin (Jet, Artigos Odontológicos Clássico Ltd.) in a metallic matrix to standardize the positioning with 30° of inclination in relation to the vertical axis. This procedure allowed oblique loading with the misfit opposite to the loading surface. An autopolymerizing acrylic resin was used an embedded material due to its appropriate elastic modulus for a bone analog material (the bone's elastic modulus can range from 1.37 GPa for tradecular bone to 13.7 GPa for cortical bone) [29,30]. Also, acrylic resin is easily manipulated and is sufficiently tough for cyclic testing. According to manufacturer's information the resin used in the present study has an elasticity modulus higher than 3 GPa. Therefore, it is in accordance with International Organization for Standarization 14801 for Dentistry-fatigue test for endosseous dental implants, in which the embedded material should present an elastic modulus higher than 3 GPa [31].

The implants were randomly divided into the four groups (A, B, C and D) and attached to the crowns with titanium retention screws (PTQ 2008, SIN - Sistema de Implante) using an analogic torque gauge (BTG36CN-S, Tohnichi MFG. CO. Ltd., Tokio, Japan) with torque of 30 ± 0.5 N/cm. This torque was used according to manufacturer's recommendation. After 2 min, the screws were loosened to evaluate the initial preload maintenance through the initial detorque values.

During torque insertion and detorque measurements, the replicas were placed in a device (Metalsul, Joinvile, SC, Brazil) to place the screw access hole perpendicular to the horizontal plane. Two detorque measurements were obtained for each replica before mechanical cycling in order to obtain an initial detorque mean.