ALOÍSIO ORO SPAZZIN

TORQUE DE AFROUXAMENTO DOS PARAFUSOS PROTÉTICOS EM PRÓTESES IMPLANTO-SUPORTADAS COM DIFERENTES NÍVEIS DE DESAJUSTE

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Orientador: Prof. Dr. Marcelo Ferraz Mesquita

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“Crescer significa mudar e mudar envolve riscos,
uma passagem do conhecido para
o desconhecido”

Autor Desconhecido

RESUMO

O objetivo neste estudo foi verificar a influência da composição da liga (titânio ou ouro) e do re-aperto no torque de afrouxamento dos parafusos protéticos, sob diferentes níveis de desajustes (adaptação passiva e desajuste) de próteses mandibulares implanto-suportadas. Foram confeccionadas 10 próteses totais mandibulares implanto-suportadas e criados dois níveis de desajustes, confeccionando 20 modelos de gesso (n = 10): próteses com adaptação passiva (G1_controle); e próteses com desajuste (G2). Para G1, as estruturas protéticas foram parafusadas diretamente aos análogos de mini-pilares cônicos. Para G2, os desajustes foram simulados utilizando anéis interpostos entre os cilindros da infra-estrutura e os análogos. O objetivo da interposição dos anéis foi obter média de 250 µm de desajuste no teste do parafuso único. Os análogos de todos os conjuntos montados foram incluídos em gesso utilizando delineador. Um microscópio óptico comparador (120x) foi usado para quantificar os valores de desajuste vertical no teste do parafuso único. As estruturas protéticas foram utilizadas para os dois níveis de desajustes. O torque de afrouxamento (TA) foi avaliado utilizando parafusos fabricados em liga de titânio (Ti) ou ouro (Au), sendo avaliadas também duas técnicas de aplicação de torque (10 Ncm): 1) torque e destorque após 24 horas (SR); e 2) torque, retorque após 10 minutos e destorque após 24 horas (CR). Foi utilizado torquímetro digital (TQ8800; Lutron) para aplicação do torque e leitura do TA. Os resultados foram submetidos à análise de variância de dois fatores (ANOVA) seguida do teste de Tukey (α=0,05). Os valores médios de TA (Ncm) para parafusos de Ti foram: G1/SR=6,99(±1,03); G1/CR=7,33(±0,79); G2/SR=5,65(±1,18); G2/CR=7,24(±1,00). Para parafusos de Au foram: G1/SR=5,42(±0,99); G1/CR=5,97(±1,00); G2/SR=5,03(±1,33); G2/CR=5,71(±1,02). No Capítulo-1, os materiais dos parafusos foram comparados sem aplicação do retorque (SR): Ti apresentou valor médio de TA mais elevado, diferindo estatisticamente do de Au no G1; o G2 apresentou menor valor médio de TA, diferindo estatisticamente do G1 para Ti. Não foi encontrada diferença estatística significante entre Ti e Au no G2, ou entre G1 e G2 para Au. No Capítulo-2, o retorque foi avaliado separadamente para Ti e Au. Para parafusos de Ti: o G2/SR apresentou menor valor médio de TA, diferindo estatisticamente do G1/SR; o

G2/CR apresentou valor médio de TA mais elevado, diferindo estatisticamente de G2/SR; não foi encontrada diferença no valor médio de TA entre G1/CR e G2/CR, ou entre G1/SR e G1/CR. Para parafusos de Au, os grupos não apresentaram valores médios com diferença estatística entre si. Os materiais dos parafusos protéticos apresentaram comportamento diferente frente aos desajustes e retorque. A estabilidade da conexão dos parafusos de ouro não foi influenciada pelas variáveis avaliadas, enquanto os parafusos de titânio foram mais suscetíveis ao afrouxamento com aumento do desajuste, uma vez que o torque de afrouxamento diminuiu para valores semelhantes aos encontrados para os parafusos de ouro independentemente do nível de desajuste das próteses. Porém, a aplicação do retorque aumentou o torque necessário para afrouxar os parafusos de titânio para valores similares àqueles encontrados em próteses com adaptação passiva.

Palavras-chave: Próteses e Implantes, Adaptação, Prótese Dentária

ABSTRACT

The aim of this study was to verify the influence of alloy composition (titanium or gold) and retightening of the prosthetic screws on the loosening torque of these screws under different misfit levels (passive fit and misfit) of mandibular implant-supported prostheses. Ten mandibular implant-supported prostheses were fabricated. Two misfit levels of the prostheses were obtained fabricating twenty cast models using the prosthetic structures (n=10): prostheses with passive fit (G1_control); and prostheses with misfit (G2). For G1, the prosthetic structures were screwed directly to the analogs. For G2, the misfits were simulated using rings placed between the framework cylinders and the analogs. The analogs of all assembled sets were casted using delineator. The goal of the rings was to obtain mean of 250-μm misfit at one-screw test. An optic microscopic (120x) were used to quantifier the vertical misfit values at the one-screw test. The prosthetic frameworks were used in two misfit levels. The loosening torque (LT) was evaluated using screws made of titanium (Ti) or gold (Au) alloy, two techniques of torque application (10 Ncm) were also evaluated: 1) torque and loosening torque after 24 hours (wR); and 2) torque, retorque after 10 minutes and torque loosening after 24 hours (R). A digital torque meter (TQ8800; Lutron) was used to torque application and to measure the LT. Data were separately analyzed by two-away ANOVA followed by Tukey's test (α=0,05). The LT mean values (Ncm) for titanium screws were: G1/wR=6.99 (±1.03); G1/R=7.33(±0.79); G2/wR=5.65(±1.18); and G2/R=7.24(±1.00). For gold screws were: G1/wR=5.42(±0.99); G1/R=5.97(±1.00); G2/wR=5.03(±1.33); and G2/R=5.71(±1.02). In the Chapter-1, the screw materials were compared without retorque application (wR): Ti showed significant higher LT than Au in the G1; and G2 presented significant lower LT than G1 for Ti. No significant statistic difference was found between Ti and Au in the G2, or between G1 and G2 for Au screws. In the Chapter-2, the retorque was evaluated separately to Ti and Au. For titanium screws: the G2/wR showed lower LT than G1/wR; the G2/R presented higher LT than G2/wR; no significant difference on the LT between G1/R and G2/R; or between G1/wR and G1/R. For gold screws, the groups did not show mean values with statistic difference between each other. The prosthetic screw materials presented different behavior for the misfits and the retorque. The joint stability of the gold screw was not influenced by variables tested. While the titanium screws were more susceptible to the loosening with the misfit increase, once the loosening torque decreased to similar values those found for the gold screws regardless of the prosthetic fit level. However, the torque application increased the loosening torque of the titanium screws to similar values those found to the prostheses with passive fit.

Key-words: Prostheses and Implants, Adaptation, Dental Prosthesis.

SUMÁRIO

INTRODUÇÃO

O reconhecimento da existência de união biocompatível entre tecido ósseo e implante aloplástico criou grande número de novas aplicações na Odontologia (Hecker & Eckert, 2003). Estudos têm confirmado a longevidade de próteses fixas implanto-suportadas em pacientes desdentados parciais e totais (Adell *et al.*, 1981; Adell *et al.*, 1990; Cox & Zarb, 1987; Jemt & Lekholm, 1993; Jemt, 1994; Lindquist *et al.*, 1996; Zarb & Schmitt, 1993), sendo uma alternativa às próteses convencionais. Porém, complicações biológicas ou mecânicas têm sido relatadas, principalmente, pelo desajuste neste tipo de reabilitação (Kan *et al.*, 1999).

Complicações biológicas podem incluir reações adversas dos tecidos, dor, sensibilidade, reabsorção do osso marginal, e até falha da osseointegração (Adell *et al.*, 1981; Bauman *et al.*, 1992; Haanaes, 1990). Entretanto, estudos têm mostrado existir certa tolerância biológica da interface implante e tecido ósseo para determinados níveis de desajustes (Carr *et al.*, 1996; Jemt & Book, 1996; Kallus & Bessing, 1994; Michaels *et al.*, 1997). Abreu (2007) avaliou o efeito da amplificação do desajuste vertical sobre a distribuição de tensões em uma barra sobre dois implantes osseointegrados, usada para retenção adicional em próteses totais (Overdentures), por meio do método dos elementos finitos utilizando um modelo tridimensional. O autor concluiu que o aumento do desajuste não teve influência considerável nos níveis de tensões sobre o tecido ósseo peri-implantar, porém proporcionou aumento significante nos níveis de tensões na estrutura da barra. Estes resultados podem sugerir diferença sobre os níveis de tolerância entre complicações biológicas e mecânicas de próteses implanto-suportadas com a passividade deficiente.

Quanto às complicações mecânicas, podem incluir o afrouxamento dos parafusos protéticos e pilares, ou fratura de vários componentes do sistema (Gunne *et al.*, 1994; Naert *et al.*, 1992; Zarb & Schmitt, 1990). A instabilidade ou afrouxamento dos parafusos protéticos é uma complicação freqüentemente reportada em reabilitações com implantes (Behr *et al.*, 1998; Jemt, 1991; Jemt *et al.*, 1992; Jemt & Lekholm, 1993; Jemt, 1994; Kallus & Bessing, 1994; Naert *et al.*, 1992). Embora o afrouxamento não seja uma complicação para o próprio parafuso, podem induzir complicações mais sérias para os demais componentes do sistema (al-Turki *et al.*, 2002). O afrouxamento de um determinado parafuso em próteses múltiplas não é percebido pelo paciente e muitas vezes não verificado pelo profissional, isso implica em sobre-carga aos demais parafusos que poderão também afrouxar. Esta seqüência de acontecimentos pode favorecer a ocorrência de falhas, seja por fratura de componentes, seja por perda óssea ao redor dos implantes ainda torqueados, devido à sobrecarga de tensão exercida sobre as conexões e interface osso-implante.

Os dentes naturais podem se mover dentro do alvéolo devido ao ligamento periodontal, podendo acomodar-se a certas discrepâncias. Porém, os implantes osseointegrados não possuem ligamento periodontal, tendo sua mobilidade limitada pela elasticidade óssea (Richter, 1989). Deste modo, a literatura sugere o requerimento de adaptação passiva entre os cilindros da estrutura protética e os pilares, ou aos próprios implantes (Kan *et al.*, 1999). Alguns autores (Branemark, 1983; Jemt, 1991; Klineberg & Murray, 1985) têm tentado definir um nível aceitável de desajuste para próteses sobre implantes. Branemark (1983) foi o primeiro a definir adaptação passiva, e propôs que deveria existir desajustes de até 10 µm, para permitir a maturação e remodelação ósseo em resposta às cargas oclusais. Jemt (1991) definiu adaptação passiva como nível de desajuste que não causasse qualquer complicação (biológica ou mecânica) ao longo do tempo, sugerindo que valores de desajuste menores que 150 µm seriam aceitáveis clinicamente. Embora estes valores sejam usados como referência e citados subseqüentemente, são de origem empírica.

As técnicas convencionais de laboratório, fundição em monobloco, não permitem a confecção de infra-estruturas rígidas com níveis aceitáveis de adaptação, e as distorções podem ser geradas em qualquer passo do processo de confecção da peça protética (Romero *et al.*, 2000). A maioria das distorções ocorre devido à alteração volumétrica dos materiais utilizados que incluem material de impressão, gessos, ceras, revestimentos, fundição do metal e aplicação do revestimento estético (Assif *et al.*, 1996; Carr, 1991; Carr & Stewart, 1993; Gettleman & Ryge, 1970; Humphries *et al.*, 1990; Inturregui *et al.*, 1993; Linke *et al.*, 1985; Valadares, 2007). Muitos autores têm recomendado vários métodos para melhorar a adaptação em próteses implanto-suportadas, que incluem técnicas de impressão (Assif *et al.*, 1996; Carr, 1991), soldagem (Parel, 1989), eletro-erosão (Romero *et al.*, 2000;

Sartori *et al.*, 2004; Schmitt & Chance, 1996), e sistema CAD-CAM (Riedy *et al.*, 1997; Tan, 1995). No entanto, vários destes afirmam que ainda são necessários mais dados que definam o limite para que o assentamento da infra-estrutura seja clinicamente aceitável, sugerindo que certo grau de desajuste é uma realidade clínica para próteses múltiplas.

A literatura sugere que além da falta de passividade das próteses (McAlarney & Stavropoulos, 1996), vários outros fatores podem influenciar na instabilidade dos parafusos protéticos, entre eles o torque insuficiente (Gross *et al.*, 1999; Haack *et al.*, 1995; McGlumphy, 1993), assentamento ou relaxamento do parafuso (Jorneus *et al.*, 1992; Siamos *et al.*, 2002), e diferença na forma e material do parafuso (Guda *et al.*, 2008; Haack *et al.*, 1995; Jorneus *et al.*, 1992; Kallus & Bessing, 1994; Martin *et al.*, 2001).

Estudos têm avaliado a influência do material do parafuso do pilar na estabilidade da conexão (Haack *et al.*, 1995; Martin *et al.*, 2001; Stüker *et al.*, 2007). Porém, a conexão parafusada entre um implante e um pilar usinado está em estado passivo, uma vez que quando um parafuso é submetido a um determinado torque, as forças criadas serão somente a força de fixação e a pré-carga, inerentes as conexões parafusadas (Bickford, 2007). No caso de próteses múltiplas implanto-retidas que não apresentam adaptação perfeita, são criadas tensões residuais estáticas, e a magnitude destas tensões depende da amplitude do desajuste (Millington & Leung, 1995; Uludamar & Leung, 1996). Outro fator pouco explorado é o assentamento do parafuso após aplicação do torque. Siamos *et al.* (2002) avaliaram efeito do retorque 10 minutos após o torque inicial de aperto em pilares intermediários, sugerindo um modo fácil e rápido para aumentar a estabilidade da conexão. Porém, este fator também não tem sido avaliado para parafusos protéticos em próteses múltiplas implanto-suportadas. Dessa maneira, o objetivo do presente estudo foi investigar os efeitos do material utilizado na fabricação dos parafusos protéticos, e do retorque (10 Ncm) após 10 minutos do torque inicial de aperto (10 Ncm) destes parafusos sob dois níveis de desajustes entre intermediários e cilindros de próteses mandibulares totais implanto-suportadas. Na primeira parte desta investigação (Capítulo 1), o material do parafuso foi avaliado, e na segunda parte (Capítulo 2), o efeito do retorque sobre estes parafusos.

O presente trabalho é apresentado no formato alternativo de dissertação de acordo com as normas estabelecidas pela deliberação 002/06 da Comissão Central de Pós-Graduação da Universidade Estadual de Campinas. Os artigos referentes aos Capítulos 1 e 2 foram submetidos aos periódicos *The International Journal of Oral & Maxillofacial* e *The Journal of Prosthodontics: Implant, Esthetic, and Reconstructive Dentistry*, respectivamente.

CAPÍTULO 1

Stability of prosthetic screws made of different materials at two levels of fit of implant-supported dentures

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Abstract: This study evaluated the influence of alloy composition of prosthetic screws on joint stability in mandibular implant-supported dentures with different levels of fit. Ten mandibular implant-supported dentures were fabricated. Twenty cast models were also fabricated, using prosthetic structures to create two levels of fit as follows (n=10): passive fit (Pf) and misfit (Mf). The one-screw test was performed to quantify the vertical misfits using an optic microscope. The loosening torque for the gold (Au) and titanium (Ti) prosthetic screws was measured 24 hours after tightening torque, considering the different levels of fit, creating 4 groups. A digital torque meter was used for the tightening and the loosening torque. Data were analyzed by two-way ANOVA followed by Tukey's test ($\propto$ = 0.05). Mean loosening torque values in Ncm were: Ti-Pf = 6.99 (±1.03); Ti-Mf = 5.65 (±1.18); Au-Pf = 5.42 (±0.99); and Au-Mf = 5.03 (±1.33). Ti-Pf showed significantly higher loosening torque values than Au-Pf; and the Ti-Mf presented significantly lower loosening torque values than Ti-Pf. No significant differences were found between Ti-Mf and Au-Mf, or between Au-Pf and Au-Mf groups. The titanium screws presented higher joint stability in dentures with passive fit than the gold screws. However, the joint stability of the titanium screws was more susceptible to loosening in the case of misfit, since it was observed that they reduced loosening torque to values similar to those found for gold screws.

Keywords: prosthetic screw materials, misfit, implant-supported dentures, screw joint stability.

Running Heads: PROSTHETIC SCREWS AND MISFIT: SCREW JOINT STABILITY

INTRODUCTION

Recognition of a biocompatible union (osseointegration) between the bone tissue and dental implant created a number of new applications in the field of dentistry, offering treatment options for edentulous and partially edentulous patients.(1) The use of dental implants to support and retain dental prostheses has been shown to be clinically efficacious.(2-7) However, lack of passivity of implant-supported dentures may cause biologic complications of the surrounding tissues, or mechanical failures of the dentures and implant systems.(8) Biological complications may include adverse tissue reactions, pain, tenderness, marginal bone loss, and loss of osseointegration;(4, 9-11) nevertheless, several studies have shown that osseointegrated implants have some biologic tolerance for certain levels of misfit.(11-14)

Mechanical complications may include loosening of the prosthetic and abutment screws or fracture of various components in the system.(15-17) Instability or loosening of prosthetic screws are frequently reported complications in dental implant therapy.(11, 16, 18-20) Although loosening of screws is not a complication in itself, it may induce more serious complications to others components.(21) Professionals or patients do not perceive the loosening of one screw in multi-unit dentures, which implicates overload on another screw that can also loosen. These ongoing sequences may favor the occurrence of failures, resulting in component fractures or loss of bone tissue surrounding the implants that still have tightened screws, due to overload of stress on the screw joints and bone-implant interface. The literature suggests that in addition to the lack of passivity of the dentures,(22) several factors can contribute to screw instability: namely, insufficient tightening torque,(23-25) biomechanical overload,(23) screw settling,(26, 27) and differences in screw material or design.(11, 24, 28-30)

Some studies have evaluated the influence of the abutment screw material on joint stability.(24, 29, 30) The screw joint between implant and machined abutment is in a passive state after the torque applied to the screw. When a screw is submitted to a certain torque in screw joints in a passive state, the only forces created are the clamping forces and preload.(31) Since multi-unit implant dentures do not present a perfect fit, residual static stresses are thus created in relation to the misfit size,(32, 33) suggesting that these residual static stresses could provide differences in screw joint behavior between multiple-unit and single-unit implant-retained dentures. There is very limited information about the effects of different prosthetic screw materials on joint stability in multiple-unit dentures. Therefore, the aim of this study was to evaluate the loosening torque of prosthetic screws made of two different materials (titanium and gold alloy) at two levels of fit (passive fit and vertical misfit) in mandibular implant-supported dentures.

MATERIALS AND METHODS

Experimental Design

Ten mandibular implant-supported dentures were fabricated. Twenty cast models (10 with passive fit and 10 with misfit) were the fabricated using the prosthetic structures. The loosening torque of the prosthetic screws made of different materials (Table 1) used to retain the dentures was tested at two different levels of fit (passive fit and misfit). Screws were assigned to 4 groups: 1) gold/passive fit; 2) gold/misfit; 3) titanium/passive fit; and 4) titanium/misfit.

Prosthetic structure fabrication

A metallic matrix was fabricated and five conical abutment analogs (4.1 mm Micro-unit; Conexão Prostheses Systems, São Paulo, SP, Brazil) fixed to it with transversal screws. The abutment analog disposition (A, B, C, D and E) used in this study simulates a clinical situation of five implants placed between mental foramens, arranged in an arc mode, with 10-mm inter-implant spaces (Figure 1). A master cast was then fabricated using a splinted impression technique to allow the waxing of ten prosthetic frameworks with calcinable cylinders (Conexão Prostheses Systems) and bar wax cylinders (Wax wire 4.0; Dentaurum, Pforzheim, Alemanha). The free ends were standardized at a 10-mm distal extension. The frameworks were then casted in cobalt-chromo alloy (Dentaurum) using the lost-wax casting technique. Heat-polymerized acrylic resin (Clássico, São Paulo, SP, Brazil) and artificial teeth (Vipi Plus; VIPI, Pirassununga, SP, Brazil) were used as veneering material.

Fit condition simulation

Twenty cast models (10 for passive fit and 10 for misfit) were fabricated using the prosthetic structures maintaining the abutment analog positions to simulate the two fit levels tested. The assembling of the components concerning the fit levels is shown in Figure 2. For the passive fit, no rings were used between the abutment analogs (4.1 mm Micro-unit; Conexão Prostheses Systems) and framework cylinders of the prosthesis. For the misfit, three rings of different thicknesses (100, 200 and 300 μm, one for each analog, respectively) were used between three of the framework cylinders of the prosthesis and the abutment analogs (C, D and E); the others abutment analogs (A and B) were screwed directly to the framework cylinders. All these sets were invested in the stone cast (type IV Herostone; Vigodent, Rio de Janeiro, RJ, Brazil) using a delineator (Figure 3). The rings were added to create a vertical prosthetic misfit of approximately 250 μm; the one-screw test was then used to quantify the two fit levels tested (Figure 4).

Fit Evaluation (One-Screw Test)

An optic microscope (VMM-150; Walter Uhl, Asslar, Germany) was used to measure the vertical misfit at 120x magnification. The technique used to measure the vertical misfit was based on the one-screw test protocol.(34) This technique involved one titanium screw (Conexão Prostheses Systems) tightened to 10 Ncm onto the abutment “A” using a manual torque meter (Conexão Prostheses Systems). Vertical misfits between platform abutment analogs and the inferior border of the denture framework cylinders were then measured, three times, considering the buccal and lingual faces of the abutments “C” and “E”. Next, the titanium screw was loosened and replaced with another screw tightened to 10 Ncm onto abutment "E", and the vertical misfit of the abutments "C" and "A" were evaluated as was done previously.

A total of 24 vertical misfit values were obtained for each prosthetic structure and its cast model, and then the mean of these values was calculated to determine the misfit of the prosthesis. The mean values and standard deviations (SD) with regard to vertical misfit were: 51 μm (±23) for passive fit; and 264 μm (±78) for misfit.

Loosening Torque Evaluation

The loosening torque was evaluated using a digital torque meter with a 0.1-Ncm precision (TQ8800; Lutron, Taipei, Taiwan), involving 20 screw sets (5 screws in each set) of titanium alloy and 20 screw sets of gold alloy. One calibrated researcher performed the loosening torque. The cast models were fixed to a laboratory desk using a metal peg, and the prosthetic screws were tightened (10 Ncm) in the sequence B, D, C, A and E.(35) The loosening torque was evaluated 24 hours after the initial tightening torque following the same tightening sequence (B, D, C, A and E). The loosening torque of a determined prosthetic screw was evaluated, and this screw was again tightened (10 Ncm) to its abutment, thus the loosening torques of the other prosthetic screws were measured with all the other screws tightened.

The mean loosening torque values (Ncm) of the screw sets were submitted to two-way (fit x screw material) analysis of variance (ANOVA) followed by Tukey's test ($\alpha=0.05$).

RESULTS

Table 2 shows results with regard to the loosening torque involving all groups. Two-way ANOVA followed by Tukey's test showed higher loosening torque values for the titanium screws when compared with the gold screws, in the dentures with passive fit ($p < 0.05$). However, the screw materials (titanium and gold alloy) had no significant influence on the loosening torque as regards the dentures with misfit ($p = 0.232$). The titanium screws presented significantly lower loosening torque values in dentures with misfit when compared with those observed in dentures with passive fit ($p < 0.05$). While no significant difference was observed between the levels of fit tested as regards the loosening torque for gold screws ($p = 0.445$).

DISCUSSION

The titanium screws presented higher loosening torque than gold screws in the situation of maximum passivity of the dentures. To explain this result, it is primarily necessary to know some engineering concepts. The aim of a screw or group of screws in almost all joints is to create a clamping force between two or more objects, which are called joint members. The clamping force is the compressive force that two joint members exert on each other, created by the force the screws are exerting on them. The clamping force on the joint is initially created when joint is assembled and the screws are tightened. This action also creates tension in the screws; this tension is usually called preload at this stage. Although there may be some plastic deformation in some of the threads when a screw is tightened normally, most of the screws and the joint members respond elastically as the screws are tightened.(31) These concepts can explain the previously related result; in other words, the titanium screw probably showed lower plastic deformation in dentures with passive fit than the gold screws, suggesting a higher joint stability. Guda et al. (2008) evaluated the preload on a screw abutment using finite element analysis.(28) The authors suggested that materials with higher elastic modulus should be used in the manufacture of the abutment screws to achieve higher preload, in agreement with the results of the present study under a passive fit condition.

The stresses found in a screw joint in a passive state after torque applied to the screw, are the clamping forces and preload only.(31) In implant dentures, this passive state may be observed in premachined abutments when used in single-unit dentures. The theoretical ideal would be a perfect fit of implant dentures, but this situation is not found clinically for multiple-unit implant dentures. Some authors have attempted to define an acceptable level of implant prosthesis fit.(18, 36) In 1983, Branemark was the first to define passive fit and he proposed that this should be at the level of 10 μm to enable bone maturation and remodeling in response to occlusal loads.(36) In 1991, Jemt defined passive fit as level that did not cause any long-term clinical complications and suggested misfits smaller than 150 μm were acceptable.(18) Although the preceding values were reported, and subsequently used as reference, they are of empirical origin.

The mean vertical misfit value was 51 (±23) μm for the dentures placed on the cast models with passive fit, among those referred to as clinically acceptable. While the mean vertical misfit value was 263 μm (±78) for the dentures placed on the cast models with misfit, higher than those referred to as clinically acceptable. In the present study, the misfit condition reduced the joint stability for the titanium screws, showing loosening torque values similar to those found for the gold screws. Whereas the different levels of fit showed no influence on the loosening torque for the gold screws.

When prosthetic screws used to retain multiple-unit dentures are submitted to a tightening torque, the ideal would be that only the clamping forces and preload were generated, as in single-unit dentures. However, conventional dental laboratory techniques do not allow a framework to be fabricated without the presence of misfits.(37) The errors are mostly due to the volumetric inconsistency and linear expansion of the materials used in framework fabrication, which include impression material, gypsum products, waxes, investments, and casting metal; in other words, potential distortion can be created at any step of the fabrication process.(38-43) Some studies have shown that the levels of static stresses created in a framework depended on the misfit size.(32, 33) In this context, the lower malleability and higher frictional resistance of the titanium screws could have permitted a smaller contact area between the screw threads and opposing flanges of the abutment than the gold screws did, suggesting higher sensitivity of the titanium screw to residual static stresses.

In addition, some studies have related a higher preload on gold than on titanium screws in abutments of single-unit dentures, suggesting higher restoration longevity when using gold screws.(29, 30) However, these studies did not use mechanical fatigue. Further investigation is fundamental to evaluate the behavior of the prosthetic screw materials as regards misfits under cyclic loading. Another limitation of this study is related to the simulated misfits, since only vertical misfits were created, while horizontal and angular misfits are also generated in implant-supported dentures during their fabrication. Horizontal and angular misfits result in generating bending stresses in the implant components.(32) Further studies are necessary to evaluate the effects of these stresses generated by horizontal and angular misfits on joint stability as well as the surrounding bone tissue.

CONCLUSION

Within the limitations of this *in vitro* study, it can be stated that the prosthetic screw materials showed a difference in behavior with regard to the screw joint stability. The different levels of fit tested did not affect the loosening torque for the gold screws. The titanium screws presented higher loosening torque values than gold screws in dentures with passive fit. However, the joint stability of the titanium screws was more susceptible to loosening as regards misfit, since it was observed that they reduced the loosening torque to values similar to those found for gold screws.

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TABLE 1. Prosthetic screws used in the study.

Prosthetic screw	Manufacturer	Alloy composition*
Gold alloy	Conexão Prostheses Systems	68.5% Au, 8.5% Ag, Cu% 23, ≤ 0.0014% Pb, Zn, Ni, Cd, Co, and Pd
Titanium alloy	Conexão Prostheses Systems	90% Ti, 6% Al, and 4% V

* Alloy composition percentages obtained from the manufacturers.

TABLE 2. Means (standard deviations) of loosening torque (Ncm) of screw materials in different levels of fit.

Fit	Screw material	
	Titanium	Gold
Passive fit	6.99 (1.03) ^{A,a}	5.42 (0.99) ^{B,a}
Misfit	5.65 (1.18) ^{A,b}	5.03 (1.33) ^{A,a}

Means followed by distinct capital letters in the same line, and small letters in the same column, were significantly different at $p < 0.05$.

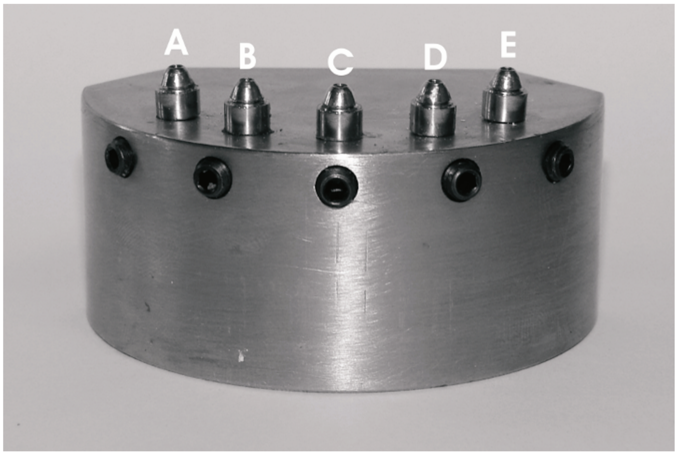

Figure 1. Metal matrix and abutment analog disposition.

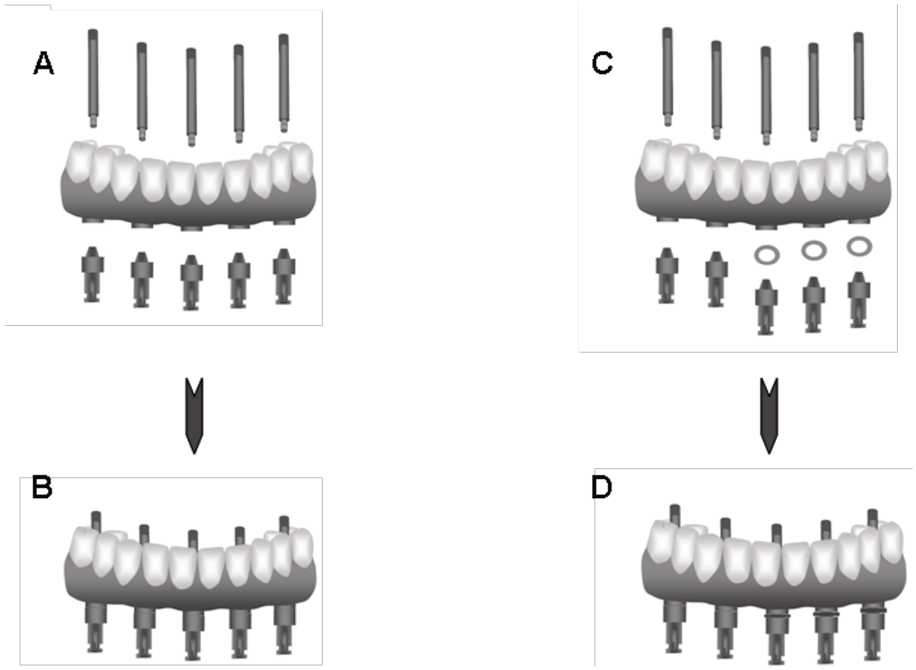

Figure 2. Schematic illustrations of assembling the components to simulate the different levels of fit: (A) components in passive fit; (B) components assembled in passive fit; (C) components in misfit; (D) components assembled in misfit with rings (± 100, 200 and 300 µm of thickness) inserted between cylinders and abutment analogs.

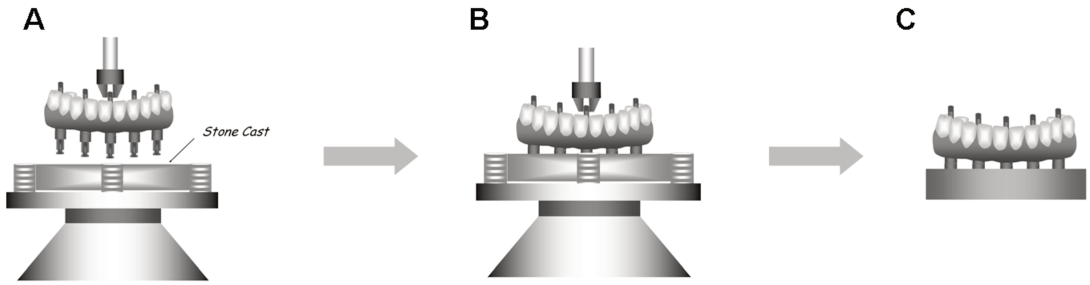

Figure 3. Schematic illustrations of the cast model fabrication: (A) set assembled; (B) abutment analogs were invested in stone cast; (C) cast models removed from the delineator.

Figure 4. Schematic illustrations of the two fit conditions submitted to the one-screw test: (A) passive fit; (B) vertical misfit.

CAPÍTULO 2

Effect of retorque on stability of prosthetic screw under two levels of fit of implant-supported dentures

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Purpose: This study evaluated the influence of retorque application on screw joint stability of prosthetic screws in mandibular implant-supported dentures with different levels of fit. **Materials and methods:** Ten mandibular implant-supported dentures were fabricated. Twenty cast models were then fabricated using prosthetic structures to create two levels of fit, as follows (n=10): passive fit (Pf) and misfit (Mf). One-screw test was performed to quantify the vertical misfits using an optic microscope. The torque required to loosen the prosthetic screws was measured 24 hours after the initial tightening torque (10 Ncm) using two tightening techniques of these screws considering the different levels of fit: initial torque only (T1); and initial torque and retorque after 10 minutes (T2). Gold and titanium screws were evaluated separately. A digital torque meter was used for the tightening and loosening torque. Data were analyzed by two-way ANOVA followed by Tukey's test ($\propto$=0.05) separately for each screw material. **Results:** For the titanium screws: Mf reduced the loosening torque significantly using T1; T2 increased the loosening torque for Mf; no significant difference was found between Pf and Mf using T2; or between T1 and T2 for Pf. The independent variables had no significant influence on the loosening torque for the gold screws. **Conclusions:** Titanium screws presented higher torque loss for the dentures with misfit than for those with passive fit; however, the retorque increased the joint stability of these screws in dentures with misfit to levels similar to those found in the passive fit condition. Retorque and levels of fit were shown to have no influence on the joint stability of the gold screws.

Key words: retorque, misfit, implant-supported prostheses, screw joint stability.

INTRODUCTION

Lack of passivity of implant-supported dentures may cause biologic complications of the surrounding tissues, or mechanical failures of the dentures and implant systems.(1) Biological complications may include adverse tissue reactions, pain, tenderness, marginal bone loss, and loss of osseointegration;(2-5) nevertheless, several studies have shown that osseointegrated implants have some biologic tolerance for certain levels of misfit.(5-8)

Mechanical complications may include loosening of the prosthetic and abutment screws or fracture of various components in the system.(9-11) Instability or loosening of prosthetic screws are frequently reported complications in dental implant therapy.(5, 10, 12-14) Although loosening of screws is not a complication in itself, it may induce more serious complications to others components.(15) Professionals or patients do not perceive the loosening of one screw in multi-unit dentures, which implicates overload on another screw that can also loosen. These ongoing sequences may favor the occurrence of failures, resulting in component fractures or loss of bone tissue surrounding the implants that still have tightened screws, due to overload of stress on the screw joints and bone-implant interface. The literature suggests that in addition to the lack of passivity of the dentures,(16) several factors can contribute to screw instability: namely, insufficient tightening torque,(17-19) biomechanical overload,(19) differences in screw material or design,(5, 18, 20-22) and screw settling.(22, 23)

When a certain torque is applied to a screw, the energy is expended in smoothing surface irregularities for maintaining the surfaces together. After thread engagement, surface asperities are flattened and additional input torque is applied toward elongation of the screw and generation of preload.(24) Siamos et al. (2001) evaluated the effect of retightening some time after initial tightening torque, on the screw joint stability of the abutment screws, suggesting an easy and fast method to increase the joint stability (23). The screw joint between implant and machined abutment is in passive state after the torque applied to the screw. The forces created within the screw joints in the passive state are the clamping forces and preload only.(25) Multi-unit implant dentures do not present a perfect fit, thus residual static stresses are created and their magnitude depends on the misfit amplitude,(26, 27) suggesting that these residual static stresses could change the behavior of the screw joint stability of multiple-unit when compared with simple-unit implant dentures. There is very limited information about the effects of retightening after a time of settling of the prosthetic screws, on joint stability in multi-unit dentures. Therefore, the aim of this study was to evaluate the effect of retightening the screws 10 minutes after the initial tightening torque (retorque) on the loosening torque of prosthetic screws at two levels of fit (passive fit and vertical misfit) in mandibular implant-supported dentures.

MATERIALS AND METHODS

Experimental Design

Ten mandibular implant-supported dentures were fabricated. After this, twenty cast models (10 with passive fit and 10 with misfit) were fabricated using the prosthetic structures. Two prosthetic screw tightening techniques were tested on the loosening torque for two different levels of fit (passive fit and misfit) of the dentures. Forty screw sets made of titanium and 40 of gold alloy (Table 1) were evaluated separately and were assigned to 4 groups each (n=10): 1) without retorque/passive fit; 2) without retorque/misfit; 3) retorque application/passive fit; and 4) retorque application/misfit.

Prosthetic structure fabrication

A metal matrix was fabricated and five conical abutment analogs (4.1 mm Micro-unit; Conexão Prostheses Systems, São Paulo, SP, Brazil) were fixed to it with transversal screws. The abutment analog disposition (A, B, C, D and E) used in this study simulates a clinical situation of five implants placed between mental foramens, arranged in an arch mode, with 10-mm inter-implant spaces (Figure 1). A master cast was then fabricated using a splinted impression technique to allow the waxing of ten prosthetic frameworks with calcinable cylinders (Conexão Prostheses Systems) and bar wax cylinders (Wax wire 4.0;

Dentaurum, Pforzheim, Alemanha). The free ends were standardized at a 10-mm distal extension. The frameworks were then cast in cobalt-chromo alloy (Dentaurum) using the lost-wax casting technique. Heat-polymerized acrylic resin (Clássico, São Paulo, SP, Brazil) and artificial teeth (Vipi Plus; VIPI, Pirassununga, SP, Brazil) were used as veneering material.

Fit level simulation

Twenty cast models (10 for passive fit and 10 for misfit) were fabricated using the prosthetic structures, maintaining the abutment analog positions to simulate the two levels of fit tested. Assembly of the components with regard to the levels of fit is shown in Figure 2. For the passive fit, no rings were used between the abutment analogs (4.1 mm Micro-unit; Conexão Prostheses Systems) and framework cylinders of the prosthesis. For the misfit, three rings of different thicknesses (100, 200 and 300 μm, one for each analog, respectively) were used between three of the framework cylinders of the prosthesis and abutment analogs (C, D and E); the other abutment analogs (A and B) were screwed directly to the framework cylinders. All these sets were invested in the stone cast (type VI Herostone; Vigodent, Rio de Janeiro, RJ, Brazil) using a delineator (Figure 3). The rings were added to create a vertical prosthetic misfit of approximately 250 μm; the one-screw test was then used to quantify the two levels of fit tested (Figure 4).

Fit Evaluation (One-Screw Test)

An optic microscope (VMM-150; Walter Uhl, Asslar, Germany) was used to measure the vertical misfit at 120x magnification. The technique used to measure the vertical misfit was based on the one-screw test protocol.(28) This technique involved one titanium screw (Conexão Prostheses Systems) tightened to 10 Ncm onto the abutment "A" using a manual torque meter (Conexão Prostheses Systems). Vertical misfits between platform abutment analogs and the inferior border of the denture framework cylinders were then measured, three times, considering the buccal and lingual faces of the abutments "C" and "E". Next, the titanium screw was loosened and replaced with another screw tightened to 10 Ncm onto abutment “E”, and the vertical misfit of the abutments “C” and “A” were evaluated as was done previously.

A total of 24 vertical misfit values were obtained for each prosthetic structure and its cast model, and then the mean of these values was calculated to determine the misfit of the prosthesis. The mean values and standard deviations (SD) concerning the vertical misfit were: 51 μm (±23) for passive fit; and 264 μm (±78) for misfit.

Loosening Torque Evaluation

The loosening torque was evaluated using a digital torque meter with a 0.1-Ncm precision (TQ8800; Lutron, Taipei, Taiwan), involving 40 screw sets (5 screws in each set) of titanium alloy and 40 screw sets of gold alloy. One calibrated researcher performed the loosening torque. The cast models were fixed to a laboratory desk using a metal peg, and the prosthetic screws were tightened in the sequence B, D, C, A and E.(29) Two tightening techniques were tested: 1) only the 10-Ncm initial tightening torque was applied; and 2) 10-Ncm initial tightening torque was applied to the screws, 10 minutes later the screws were retightened to 10 Ncm. The loosening torque was evaluated 24 hours after the initial tightening torque following the same tightening sequence (B, D, C, A and E). The loosening torque of a determined prosthetic screw was evaluated, and this screw was again tightened (10 Ncm) to its abutment, thus the loosening torques of the other prosthetic screws were measured with all the other screws tightened.

The mean loosening torque values (Ncm) of the screw sets were submitted to two-way (retorque x fit) analysis of variance (ANOVA) followed by Tukey’s test (α=0.05), separately for each screw material.

RESULTS

The results for gold screws are shown in Table 1, and for titanium screws, in Table 2. For gold screws, two-way ANOVA showed that the factors ‘retorque’ and ‘fit’ do not significantly interfere with loosening torque ($p = 0.085$ and $p = 0.350$, respectively). In addition, there is also no statistically significant interaction between ‘retorque’ and ‘fit’ ($p = 0.850$).

For titanium screws, two-way ANOVA followed by Tukey's test showed that these screws used in dentures with misfit presented lower loosening torque than those used in dentures with passive fit, when retorque was not applied ($p = 0.005$). On the other hand, this misfit had no significant influence on the loosening torque, when the retorque was applied on the titanium screws ($p = 0.857$). Retorque did not significantly interfere on the loosening torque when the titanium screws were used in dentures with passive fit ($p = 0.459$). However, the retorque significantly increased the loosening torque when these screws were used in dentures with misfit ($p = 0.001$).

DISCUSSION

The result of this study, which was found and expected, for all groups, irrespective of the screw material used, was that the torque necessary to remove the prosthetic screws was lower than the initial tightening torque. This in agreement with al-Turki et al. 2002.(15)

Perfectly fitting multi-unit implant dentures have been a theoretical ideal, but one seldom achieved clinically. The conventional dental laboratory techniques do not allow a framework to be fabricated without the presence of misfits.(30) The errors are mostly due to the volumetric inconsistency and linear expansion of the materials used in framework fabrication, which include impression material, gypsum products, waxes, investments, and casting metal; in other words, potential distortion can be created at any step of the fabrication process.(31-37) Based on logical deduction or personal experience, levels of acceptable fit between 10 and 150 μm have been proposed.(12, 38) The mean value of simulated vertical misfit was 51 (±23) μm for dentures with passive fit, among those referred to as clinically acceptable. While the mean value of the simulated vertical misfit was 263 μm (±78) for dentures, above values referred to as clinically acceptable.

The dentures with higher misfit values than those clinically acceptable reduced the loosening torque of titanium screws when using the conventional screw tightening technique (without retorque application). The main cause of this result probably was the generation of residual stresses in the implant-retained system. When a certain torque is applied to the screws used to retain multi-unit dentures, the ideal environment would be only the force that two joint members exert on each other and tension on the screw that was created; in the other words, the clamping force and preload.(25) Due to the ankylotic nature of osseointegrated implants any stress (static or dynamic) occurring in the system will be transmitted to its components. When a prosthesis framework with lack of passivity is harshly connected to the osseointegrated implants, extra shearing and tension stresses will be created, acting on the screw joints.(1) Therefore, higher levels of misfit increase the residual static stresses, decreasing the screw joint stability for titanium screws.

The retorque applied 10 minutes after the initial tightening torque increased the loosening torque for the titanium screws in the dentures with misfit. This finding can be explained by the hypothesis that the screw threads cannot be machined perfectly smooth;(39) part of the torque applied to the screws could have been lost to smooth the irregularities in the screw threads and abutment threads, therefore the application of a retightening torque once again after embedment relaxation or settling acted to regain preload and to increase contact area between the threads. However, the retorque did not show a significant improvement in the joint stability of titanium screws in dentures with passive fit. The greater amount of residual static stresses in dentures with misfit above the clinically acceptable values could have increased the levels of settling and plastic deformation, particularly in the titanium screws, to close the misfits. Siamos et al. (2002) evaluating the effect of retorqueing on premachined abutment screws before and after mechanical cycling, advocated that retightening abutment screws 10 minutes after initial torque application should be performed routinely during abutment-implant connections.(23) Based on this finding and that of the present study, it can be suggested that retorqueing appears to show a good possibility of increasing the joint stability of titanium screws.

The stability of gold screws was also not affected by the tested misfits and retorqueing showed no significant improvement in the loosening torque. This result could be explained by higher malleability and ductibility of the gold screws, so that the residual stresses and the settling were able to decrease the effect on the joint stability, however, there are no relevant studies stating that gold screw are more stable than titanium screws in multiple dentures. Further investigation is fundamental to enable evaluation of the behavior of the experimental conditions of the present study under cyclic loading, as well as the material of the prosthetic screws.

CONCLUSION

Within the limitations of this *in vitro* study, it can be stated that the prosthetic screw materials showed a different behavior with regard to levels of fit and tightening technique. The presence of misfit between the abutments and the framework cylinders of the dentures decreased loosening torque for the titanium screws. However, the titanium screws submitted to retorqueing increased the joint stability in dentures with misfits to levels similar to those found in dentures with passive fit, suggesting that this procedure should be performed routinely during the titanium screw tightening. For the gold screw, the tested levels of fit and tightening techniques showed no significant influence on screw joint stability.

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TABLE 1. Prosthetic screws used in the study.

Prosthetic screw	**Manufacturer**	**Alloy composition***
Gold alloy	Conexão Prostheses Systems	68.5% Au, 8.5% Ag, Cu% 23, ≤ 0.0014% Pb, Zn, Ni, Cd, Co, and Pd
Titanium alloy	Conexão Prostheses Systems	90% Ti, 6% Al, and 4% V

* Alloy composition percentages obtained from the manufacturers.

TABLE 2. Means (standard deviations) of loosening torque (Ncm) for gold screws.

Fit	**Retorque**	
	No	**Yes**
Passivity fit	5.42 (0.99) ^{A,a}	5.97 (1.00) ^{A,a}
Misfit	5.03 (1.33) ^{A,a}	5.71 (1.02) ^{A,a}

Means followed by distinct capital letters in the same line, and small letters in the same column, were significantly different at $p < 0.05$.

TABLE 3. Means (standard deviations) of loosening torque (Ncm) for titanium screws.

Fit	Retorque	
	No	**Yes**
Passive fit	6.99 (1.03) [A,a]	7.33 (0.79) [A,a]
Misfit	5.65 (1.18) [B,b]	7.24 (1.00) [A,a]

Means followed by distinct capital letters in the same line, and small letters in the same column, were significantly different at $p < 0.05$.

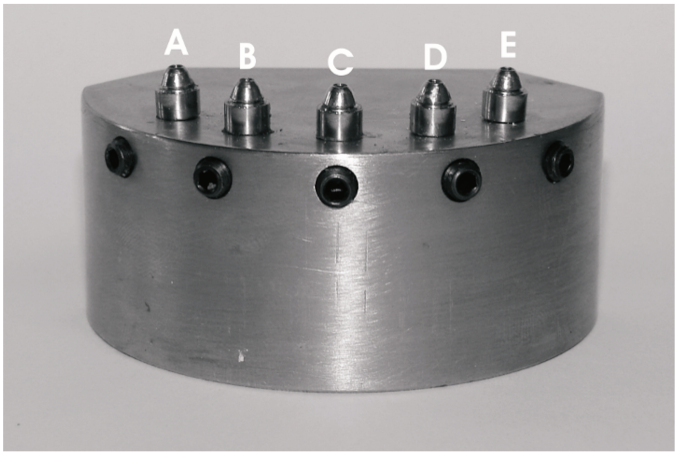

Figure 1. Metal matrix and abutment analog disposition.

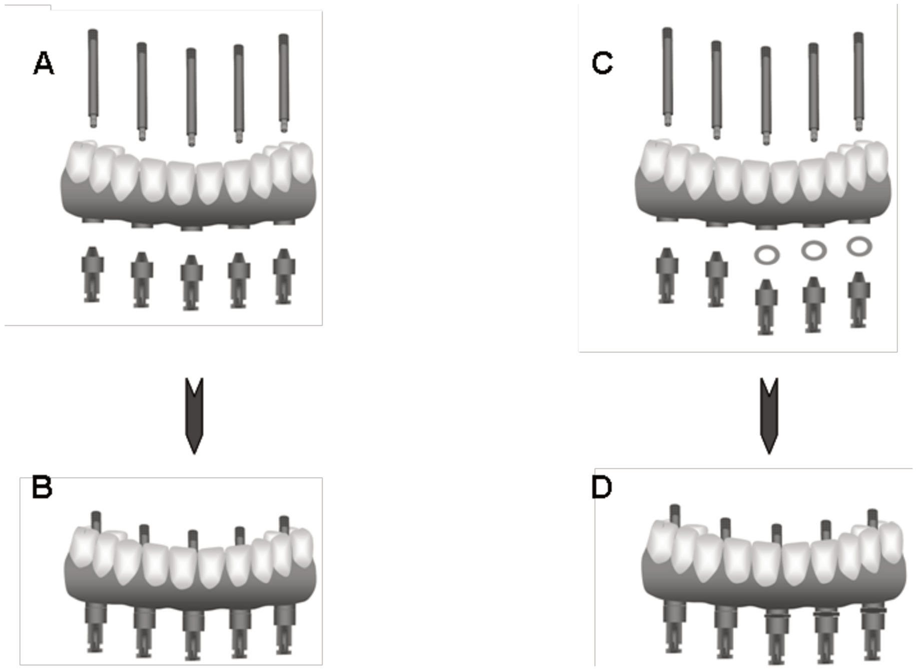

Figure 2. Schematic illustrations of assembling the components to simulate the different levels of fit: (A) components in passive fit; (B) components assembled in passive fit; (C) components in misfit; (D) components assembled in misfit with rings (± 100, 200 and 300 µm of thickness) inserted between cylinders and abutment analogs.

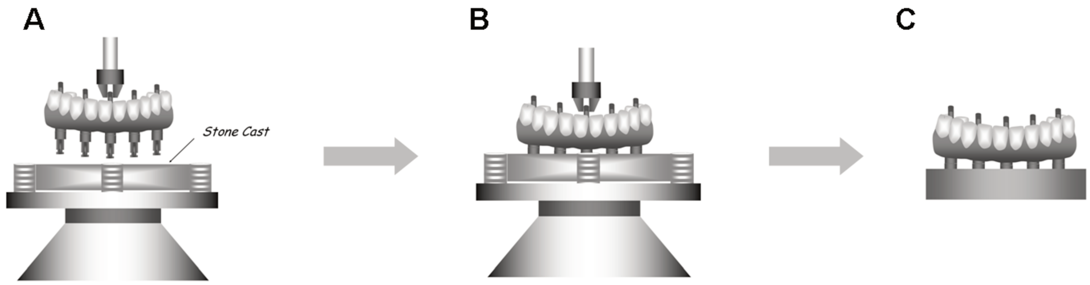

Figure 3. Schematic illustrations of the cast model fabrication: (A) set assembled; (B) abutment analogs were invested in stone cast; (C) cast models removed from the delineator.

Figure 4. Schematic illustrations of the two fit conditions submitted to the one-screw test: (A) passive fit; (B) vertical misfit.

CONSIDERAÇÕES GERAIS

A primeira etapa do estudo foi avaliar o efeito da composição da liga na estabilidade da conexão dos parafusos protéticos usados para reter próteses totais mandibulares implanto-suportadas com diferentes níveis de desajustes. Os resultados mostraram que os parafusos de titânio apresentaram boa resistência ao afrouxamento para próteses com adaptação passiva, apresentando valores mais elevados em relação aos de ouro. No Capítulo 1, foram discutidos os resultados, sendo sugerido que os parafusos de ouro podem ter deformado plasticamente em maior quantidade quando comparados aos de titânio, diminuindo a tensão (pré-carga) que é criada pela deformação elástica de um parafuso quando submetido a um determinado torque (Bickford, 2007).

Esta condição simulada de mínimo desajuste, é praticamente impossível de ser encontrada clinicamente, com as técnicas convencionais de confecção das próteses (Romero *et al.*, 2000). A literatura sugere que níveis de desajuste entre 10 e 150 μm são clinicamente aceitáveis (Branemark, 1983; Jemt, 1991). Apesar destes números serem muito citados na literatura e neste estudo, são de origem empírica. A média dos desajustes simulados para as próteses com adaptação passiva foi de 51 μm, dentro dos limites aceitáveis clinicamente, enquanto que a média dos desajustes simulados para as próteses consideradas com desajuste foi de 263 μm, ou seja, acima daqueles sugeridos como aceitáveis. Infelizmente, os níveis de desajustes são difíceis de quantificar clinicamente, e muitas vezes próteses são instaladas com desajustes acima dos avaliados neste estudo. Isso explica a necessidade de se investigar as variáveis do estudo em próteses com diferentes níveis de desajuste.

O maior desajuste diminuiu os valores médios do torque de afrouxamento dos parafusos de titânio, apresentando valores semelhantes aos de ouro, independente do nível de desajuste das próteses. Quando uma prótese múltipla é parafusada a implantes osseointegrados que possuem mobilidade limitada pela elasticidade óssea (Richter, 1989), além das forças inerentes a uma junção parafusada, tensões residuais estáticas são criadas devido aos desajustes (Abreu, 2007; Millington & Leung, 1995; Uludamar & Leung, 1996). Neste contexto, este resultado pode ser explicado pela menor maleabilidade e resistência friccional dos parafusos de titânio, que podem ter diminuído a área de contato entre as roscas dos parafusos e dos pilares, e assim as tensões residuais estáticas conseqüentes do maior desajuste podem ter aumentado a instabilidade destes parafusos. Neste contexto, pode ser sugerida uma maior probabilidade de afrouxamento dos parafusos de titânio quando as tensões sobre o sistema aumentam. Estudos adicionais são necessários para verificar o comportamento dos parafusos de titânio e de ouro sob fadiga mecânica pela mastigação simulada, para que conclusões mais precisas possam ser afirmadas e de maior relevância clínica a respeito dos materiais para fabricação dos parafusos protéticos.

A segundo etapa deste estudo foi avaliar o efeito de um re-aperto, em 10 Ncm, dos parafusos (retorque) 10 minutos após o torque inicial de aperto (10 Ncm), sobre a estabilidade dos parafusos protéticos de titânio e ouro. Os materiais foram analisados separadamente. O retorque aumentou a resistência ao afrouxamento para os parafusos de titânio quando estes foram usados para reter as próteses com desajustes acima daqueles aceitáveis clinicamente (Jemt, 1991). Como sugerido no Capítulo 2, a hipótese que pode explicar este achado é que as roscas dos parafusos e dos pilares não são perfeitamente lisas. Assim, uma parte do torque inicial de aperto é perdida para alisar estas roscas, provocando um assentamento (relaxamento) dos parafusos após certo tempo do torque. As tensões residuais geradas no sistema com maior desajuste podem ter amplificado o assentamento dos parafusos. Neste contexto, o retorque deveria ser realizado rotineiramente em parafusos de titânio usados para reter próteses múltiplas. Estes dados estão de acordo com o estudo de Siamos *et al.* (2002), mesmo usando pilares intermediários pré-fabricados.

Para os parafusos de ouro, a melhora não foi significante após a aplicação do retorque. Talvez isto tenha ocorrido pela maior maleabilidade do ouro, não necessitando um torque adicional para alisar e aumentar a área de contato entre as superfícies de contato das roscas. Da mesma forma são necessários estudos adicionais para verificar o efeito deste procedimento sobre a estabilidade da conexão destes parafusos após a ciclagem mecânica. Outra limitação, deste estudo, é relacionada aos desajustes simulados, criados somente no plano vertical, enquanto que clinicamente desajustes horizontais e angulares são gerados nestas estruturas protéticas durante sua confecção. Estes desajustes resultam em tensões de flexão nos componentes do sistema (Millington & Leung, 1995). Estudos adicionais também são necessários para verificar os efeitos destas tensões sobre a estabilidade da conexão, como também sobre o tecido ósseo circundante.

CONCLUSÃO

Dentro das limitações do presente estudo, as seguintes conclusões podem ser definidas:

1. os materiais dos parafusos protéticos avaliados apresentaram comportamento diferente frente aos desajustes e à aplicação do retorque;

2. os parafusos protéticos de titânio apresentaram maior probabilidade de afrouxamento em próteses com desajustes mais elevados, uma vez que estes desajustes diminuíram significantemente os valores médios de torque de afrouxamento destes parafusos.

3. a estabilidade dos parafusos de ouro não foi afetada pelos desajustes das próteses, e nem o retorque proporcionou melhora nesta estabilidade.

4. os parafusos protéticos de titânio submetidos ao retorque apresentaram aumento significante nos valores médios de torque de afrouxamento para prótese com desajustes.

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* De acordo com a norma da UNICAMP/FOP, baseada na norma do International Committee of Medical Journal Editors – Grupo de Vancouver. Abreviatura dos periódicos em conformidade com o Medline.

APÊNDICE

METODOLOGIA ILUSTRADA

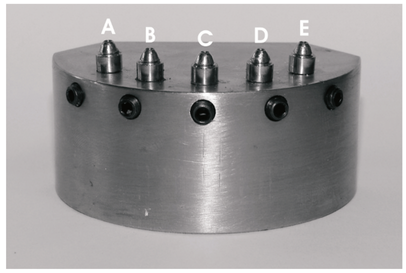

Fig. 1 – Matriz metálica e disposição dos análogos.

1. Confecção das Estruturas Protéticas

A B C

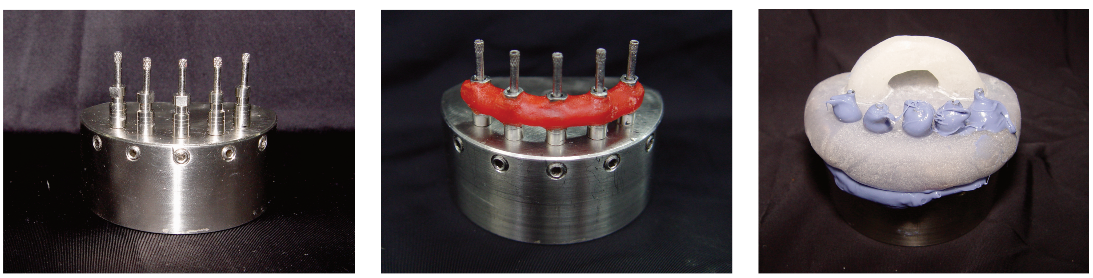

Fig. 2 – Moldagem de transferência: (A) transferentes em posição; (B) transferentes unidos; (C) moldagem.

A B C

Fig. 3 – Confecção da infra-estrutra: (A) enceramento sobre o modelo mestre; (B) enceramento posicionado no cadinho; (C) infra-estrutra fundida.

A B

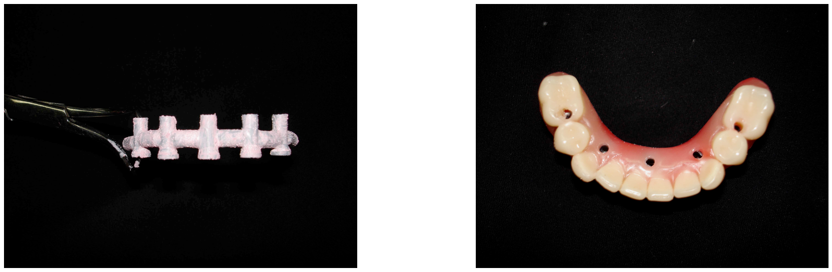

Fig. 4 – Enceramento da prótese: (A) opaco; (B) prótese encerada.

2. Simulação dos Diferentes Níveis de Adaptação

A B C

Fig. 5 – Próteses prontas: (A) as 10 próteses confeccionadas; (B) vista frontal; (C) vista inferior.

Fig. 6 – Modelos simulando a adaptação passiva das próteses: (A) parafusamento dos análogos aos cilindros da prótese; (B) conjunto montado sem anéis; (C) análogos sendo incluídos em gesso especial com o auxílio de delineador.

Fig. 7 – Modelo de gesso simulando a adaptação passiva das próteses.

A B C

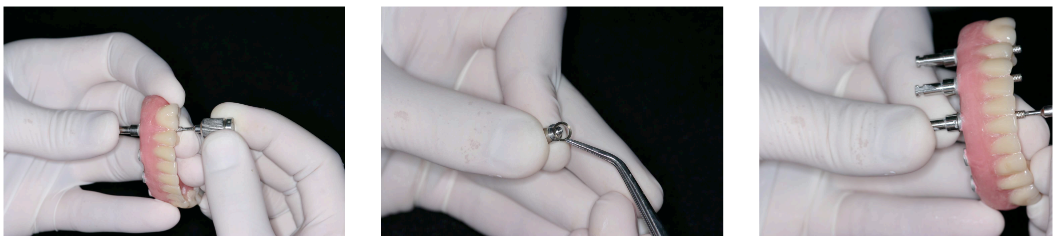

Fig. 8 – Modelos simulando próteses com desajustes acima dos clinicamente aceitáveis: (A) parafusamento dos análogos; (B) anel utilizado para criar os desaustes; (C) parafusamento do análogo C com um anel de ±100 µm.

A B

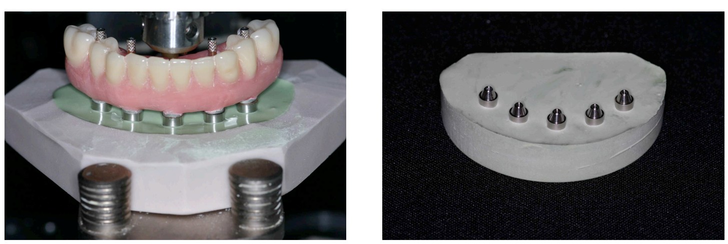

Fig. 9 – Modelos simulando próteses com desajustes acima dos clinicamente aceitáveis: (A) análogos incluídos em gesso especial com os anéis (espessuras de ±100, 200 e 300 µm) interpostos entre os cilindros e os análogos (C, D e E respectivamente); (B) modelo de gesso.

3. Teste do Parafuso Único

A B

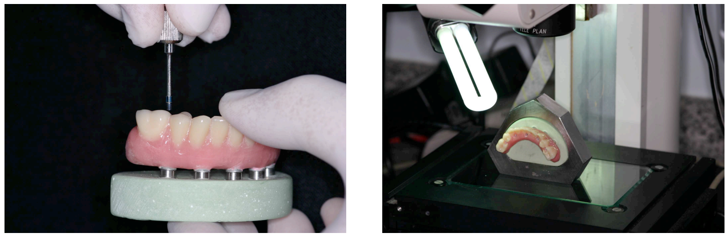

Fig. 10 – Quantificação dos desajustes pelo teste do parafuso único: (A) parafuso protético parafusado no pilar A (10 Ncm) para avaliação dos desajustes nos pilares C e E, considerando a face vestibular é lingual (este procedimento foi repetido no pilar E para avaliação dos pilares A e C); (B) avaliação dos desajustes em microscópio óptico comparador (120x).

4. Avaliação do Torque de Afrouxamento

A B C

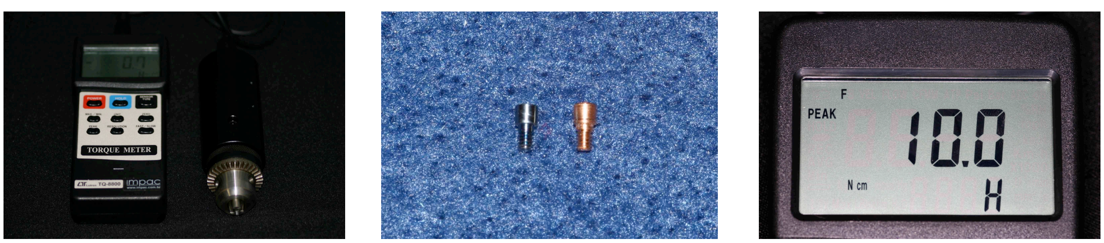

Fig. 10 – Avaliação do torque de afrouxamento: (A) torquímetro digital; (B) parafusos protéticos fabricados de titânio e de ouro; (C) aperto do parafuso com 10 Ncm (retorque em 10 Ncm foi aplicado após 10 minutos em metade das amostras).

A B

Fig. 11 – Avaliação do torque de afrouxamento: (A) os corpos-de-prova permaneceram 24 horas em repouso em temperatura ambiente; (B) mensuração do torque de afrouxamento após 24 horas, obtida por um valor negativo em Ncm.