

Marcos Boaventura de Moura

**Avaliação do comportamento biomecânico de conexões
implante-abutment cônicas internas com 11.5 e 16 graus de
angulação.**

*Evaluation of biomechanical behavior of internal tapered implant-
abutment connections with 11.5 and 16 degrees of angulation.*

Tese apresentada à Faculdade de Odontologia
da Universidade Federal de Uberlândia, para obtenção do Título de
Doutor em Odontologia na Área de Clínica Odontológica Integrada.

Uberlândia, 2020

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Orientador: Prof. Dr. Paulo César Simamoto Júnior

Banca Examinadora:

Prof. Dr. Paulo César Simamoto Júnior

Prof. Dr. Cleudmar Amaral de Araújo

Prof. Dr. Geninho Thomé

Prof. Dr. James Carlos Nery

Prof. Dr. Vítor Coró

Uberlândia, 2020

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 Coordenação do Programa de Pós-Graduação em Odontologia
 Av. Pará, 1720, Bloco 4L, Anexo B, Sala 35 - Bairro Umarama, Uberlândia-MG, CEP 38400-902
 Telefone: (34) 3225-8115/8108 - www.ppgoufu.com - copod@umarama.ufu.br



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**Dedico esta tese aos meus pais Vandir e Vany e meu irmão
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RESUMO

RESUMO

A reabilitação de pacientes desdentados com próteses sobre implantes é um tratamento estabelecido. No entanto, ainda se busca entender as causas das complicações técnicas relacionadas à conexão implante-abutment e reduzir o trauma para o paciente. As complicações técnicas mais comuns relatadas são o afrouxamento e as fraturas de parafuso e abutment. Portanto, a avaliação dos fatores causadores dessas complicações e a percepção clínica quanto ao tratamento são importantes. Assim, esta tese teve finalidade de avaliar a influência da simulação de cargas mastigatórias na força máxima suportada, afrouxamento de parafusos, força de tração (*pull-out*) e nível de tensão de conexões implante-abutment cônicas internas com 11.5 e 16 graus de angulação. Além de apresentar a reabilitação unitária de dois pacientes com acompanhamento clínico de até 24 meses. Desta forma, os objetivos desta tese foram: **Objetivo específico 1:** Verificar a influência das cargas mastigatórias na força máxima suportada em conexões cônicas internas – *Estudo in vitro*. Este estudo avaliou 3 tipos de abutments, 1 de corpo único (11.5 graus de angulação) e 2 de duas peças (11.5 e 16 graus de angulação). **Objetivo específico 2:** Avaliar a influência das cargas mastigatórias no afrouxamento de parafusos, *pull-out* de abutments de duas peças e distribuição de tensão em conexões cônicas internas. – *Estudo in vitro*. Este estudo avaliou 3 tipos de abutments, sendo 1 de corpo único (11.5 graus de angulação) e 2 de duas peças (11.5 e 16 graus de angulação). **Objetivo específico 3:** Relatar a reabilitação unitária de 2 casos de molares inferiores com instalação imediata de implantes cônicos internos com 16 graus de angulação e provisionalização imediata. Este trabalho relatou a reabilitação de 2 pacientes com próteses unitárias em molares inferiores e discutiu o impacto da utilização de abutments para prótese cimentada e parafusada. Após a análise dos dados dos estudos, pôde-se concluir que a simulação das cargas mastigatórias teve influência na força máxima suportada nas conexões de implantes com 11.5 graus, mas não influenciou nas conexões de 16 graus. O afrouxamento de parafusos das conexões testadas e o *pull-out* dos abutments de duas peças foram influenciados pelas cargas mastigatórias. A conexão de implantes com 16 graus apresentou uma melhor distribuição de

tensão. A instalação imediata de implantes cônicos internos de 16 graus e provisionalização imediata com prótese cimentada ou parafusada provaram ser protocolos exitosos para o tratamento de reabilitações unitárias, sendo capaz de minimizar a remodelação óssea e tecidual. Portanto, a correta seleção dos abutments protéticos também é uma etapa fundamental para previsibilidade do caso.

Palavras-chave: Implantes Dentários; Prótese Dentária Fixada por Implante; Reabilitação bucal.

ABSTRACT

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The rehabilitation of toothless patients with prostheses on implants is an established treatment. However, it is still sought to understand the causes of technical complications related to the implant-abutment connection and to reduce trauma to the patient. The most common technical complications reported are loosening and screw and abutment fractures. Therefore, the evaluation of the factors that cause these complications and the clinical perception regarding the treatment are important. Thus, this thesis aimed to evaluate the influence of the simulation of masticatory loads on the maximum force supported, loosening of screws, *pull-out* and stress level of internal tapered implant-abutment connections with 11.5 and 16 degrees of angulation. In addition to presenting the single-unit rehabilitation of two patients with clinical follow-up of up to 24 months. Thus, the objectives of this thesis: **Objective 1:** To verify the influence of masticatory loads on the maximum force supported in internal tapered connections – *In vitro study*. This study evaluated 3 types of abutments, 1 single-body (11.5 degrees angulation) and 2 two-piece (11.5 and 16 degrees angulation). **Objective 2:** To evaluate the influence of masticatory loads on the loosening of screws, *pull-out* of two-piece abutments and stress distribution in internal tapered connections – *In vitro study*. This study evaluated 3 types of abutments, 1 single-body (11.5 degrees angulation) and 2 two-piece (11.5 and 16 degrees angulation). **Objective 3:** To report the single-unit rehabilitation of 2 cases of lower molars with immediate placement of internal tapered implants with 16 degrees of angulation and immediate provisionalization. This study reported the rehabilitation of 2 patients with single-unit prostheses on lower molars and discussed the impact of using abutments for cemented and screwed prostheses. After analyzing the study data, it could be concluded that the simulation of the masticatory loads had an influence on the maximum force supported in the 11.5 degrees implant connections but did not influence the 16 degrees connections. The loosening of screws of the tested connections and the *pull-out* of the two-piece abutments were influenced by masticatory loads. The connection of implants with 16 degrees showed a better stress distribution. The immediate placement of 16 degrees internal tapered implants and immediate

provisionalization with cemented or screwed prosthesis proved to be successful protocols for the treatment of single-unit rehabilitation, being able to minimize bone and tissue remodeling. Therefore, the correct selection of prosthetic abutments is also a fundamental step in predicting the case.

Key-words: Dental Implants; Dental Prosthesis, Implant-Supported; Oral Rehabilitation.

INTRODUÇÃO E REFERENCIAL TEÓRICO

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

O desafio de repor dentes ausentes e de ter previsibilidade no tratamento proposto impulsionou o desenvolvimento de novos materiais e técnicas odontológicas (Pereira *et al.*, 2012). Através de anos de pesquisas e desenvolvimento, a técnica da substituição dos elementos dentários por próteses sobre implante se tornou altamente utilizada, com previsibilidade e taxas de sobrevivência altas a longo prazo (Pjetursson *et al.*, 2014). No entanto, estudos têm mostrado que ainda acontecem falhas tardias dos sistemas de implantes, e que são relatadas em uma proporção significativa (Aglietta *et al.*, 2009., Manor *et al.*, 2009).

As complicações técnicas mais comuns relacionadas à conexão implante-abutment são o afrouxamento e as fraturas de parafuso e abutment (Manzoor *et al.*, 2013). A área de conexão entre implante e abutment parece ser o local mais susceptível de ocorrência de falhas, pois é a área onde as forças funcionais da oclusão são distribuídas para a plataforma dos implantes. Em consequência, é provável que a tensão ou deformação gerados sobre a prótese causados por desajuste ou instabilidade leva a complicações técnicas (Mattheos *et al.*, 2016). Portanto, a escolha de qual o tipo de abutment utilizar em cada situação é importante, pensando na estabilidade mecânica (Macedo *et al.*, 2016).

O afrouxamento de parafusos ainda continua sendo a principal preocupação nas reabilitações implanto-suportadas (Pjetursson *et al.*, 2007, Manzoor *et al.*, 2013), principalmente em casos de próteses com reversibilidade limitada como as próteses cimentadas (Binon *et al.*, 1994). Alguns fatores podem levar ao afrouxamento e até à fratura do parafuso de fixação, como a falta de adaptação passiva e o carregamento excessivo da prótese sobre o implante resultando na instabilidade da conexão (Gonçalves *et al.*, 2010).

Então, devido aos problemas mecânicos, cada vez mais se tem buscado novos desenhos para a interface protética, onde se destaca a interface interna cônica Morse. Originalmente criado pela indústria de ferramentas mecânicas, o termo cone Morse designa um mecanismo de encaixe, onde dois elementos buscam desenvolver uma ação resultante em contato íntimo com fricção. Esse mecanismo ocorre quando um elemento/abutment “macho” cônico

é instalado numa “fêmea” também cônica, o atrito se torna significativo através do paralelismo dessas duas estruturas. Stephen A. Morse desenvolveu este tipo de encaixe, onde o ângulo Morse é determinado de acordo com as propriedades mecânicas de cada material, sendo que, nesse tipo de conexão existe uma relação entre os valores do ângulo e o atrito entre as peças (Schmitt *et al.*, 2014).

Estudos passados e atuais indicam vantagens mecânicas na estabilidade das conexões internas do tipo Morse, onde o abutment protético é unido ao implante pelo parafuso e por atrito, com travamento mecânico (friccional) entre o cone do implante e o cone do componente protético (Ricciardi Coppedê *et al.*, 2009; Fernandes *et al.*, 2011; Reis *et al.*, 2019; Thomé *et al.*, 2019). Este tipo de travamento permite que o abutment protético tenha pouca perda da pré-carga, reduzindo a possibilidade de micromovimentação durante o recebimento de cargas, não sobrecarregando o parafuso de fixação e diminuindo a incidência de afrouxamento e/ou fratura (Merz *et al.*, 2000). A conexão implante-abutment tem influência na maneira como ocorre a falha do sistema, sendo a característica de cada sistema um fator relevante para a indicação clínica (Delben *et al.*, 2014). A concentração de tensão tende a diminuir quando o ângulo da superfície interna do sistema é aumentado (Raooofi *et al.*, 2013).

A literatura relata dois tipos de abutments para reabilitação utilizando implantes cone Morse (CM): abutments de corpo único (uma peça) e parafuso passante (duas peças) (Garcia *et al.*, 2013). No abutment de duas peças (parafuso passante) o parafuso suporta um torque de travamento menor, muitas vezes sendo preconizado pelas empresas valores que chegam à metade do valor de torque utilizado no abutment de uma peça (corpo único) (Ricciardi Coppedê *et al.*, 2009). Os dois tipos de abutments apresentam uma boa resistência à carga dinâmica e podem, portanto, funcionar por vários anos sem apresentarem problemas mecânicos (Cehreli *et al.*, 2004). As características geométricas e o tipo de conexão implante-abutment são fatores importantes na estabilidade, desempenho e longevidade da reabilitação protética. Muitos sistemas de implantes CM foram desenvolvidos diante da hipótese que não existe diferença no comportamento mecânico de abutments de uma ou duas peças (Yamanishi *et al.*, 2012).

A partir da instalação de implantes em pacientes com perdas dentárias parciais e unitárias (Hsu *et al.*, 2007) começou a ficar evidente que as forças oclusais tinham influência sobre as conexões implante-abutment e deveriam ser melhor estudadas, pois eram complexas. Então, os componentes protéticos específicos para cada tipo de reabilitação começaram a ser desenvolvidos (Öhrnell *et al.*, 1988). A sobrecarga oclusal sobre o sistema protético pode causar o afrouxamento de parafusos e dependendo da situação até a fratura do componente protético (Carneiro *et al.*, 2016). Testes de simulação de fadiga têm sido realizados, considerando a angulação do sistema de implante em 30 graus, como recomenda a Norma ISO 14801 (Marchetti *et al.*, 2014; Marchetti *et al.*, 2016).

A aplicação de fadiga mecânica sobre os sistemas de implantes cone Morse faz com que ocorra intrusão e/ou deformação na interface implante-abutment, aumentando o embricamento entre as peças. Um contato mais íntimo entre as superfícies ocorrerá justapondo-os, até que não haja mais deslocamento (Messias *et al.*, 2017). Portanto, esta maior união entre os componentes favorece uma atuação conjunta, melhorando a distribuição das forças mastigatórias que incidem sobre o sistema implante-abutment (Thomé *et al.*, 2011).

No entanto, mesmo com a evolução dos sistemas de implantes, ainda é preciso estudar o comportamento mecânico destes, sendo que, as simulações de cargas dinâmicas e estáticas são meios rápidos e efetivos para gerar dados relevantes (Ugurel *et al.*, 2015; Carneiro *et al.*, 2016; de Moura *et al.*, 2017). Portanto, estudos têm usado com sucesso ensaios de fadiga para aplicação de cargas dinâmicas simulando forças mastigatórias e avaliando o afrouxamento de parafusos, que são medidos antes e/ou após a fadiga para averiguar o comportamento de cada sistema (Jorge *et al.*, 2013; Ugurel *et al.*, 2015; Pereira *et al.*, 2016). Enquanto a aplicação de cargas estáticas vai colocar uma conexão protética sob uma carga máxima suportada em um determinado ângulo definido pela norma ISO 14801 ou pelo pesquisador para avaliação da resistência à fratura (Carneiro *et al.*, 2016; Marchetti *et al.*, 2014; Marchetti *et al.*, 2016).

Ricciardi Coppedê *et al.*, em 2009, avaliaram os efeitos da carga mecânica e ciclos repetidos de inserção/remoção de abutments CM de uma e duas peças. Foram medidos os valores de torque de aperto e afrouxamento e a medida que aumentava o número de ciclos de inserção/remoção dos abutments, os valores de torque de afrouxamento tendiam a ser mais baixos e após a fadiga dinâmica aplicada os valores de afrouxamento dos abutments carregados aumentou em comparação com ou sem carregamento.

Feitosa *et al.*, em 2013, compararam os valores de torque de aperto e desaperto de abutments para próteses unitárias do tipo hexágono externo (HE), hexágono interno (HI) e CM após fadiga dinâmica. Os espécimes foram submetidos a um teste mecânico de 1.000.000 ciclos, sob uma carga de 400 N. O registro do valor do torque de aperto e desaperto foi realizado antes e depois do teste. Os resultados foram avaliados estatisticamente e mostraram que os implantes do tipo CM apresentaram uma variação menor entre os valores de aperto e desaperto e mostraram uma melhor estabilidade no caso de restaurações unitárias.

Ugurel e sua equipe, em 2015, realizaram um estudo para avaliar a resistência mecânica de conexões de implantes, sendo utilizadas três tipos de conexões: 2 internas (CM e HI) e 1 externa (HE). Um total de 32 espécimes sofreram carregamento dinâmico e 32 sofreram carregamento estático. O carregamento dinâmico foi realizado com uma força 120 N (1,75 Hz) para $1,2 \times 10^6$ ciclos, e o carregamento estático foi realizado com uma máquina universal de ensaios a uma velocidade de 2 mm/min, ambos com uma angulação de 30 graus. Foram registrados os ciclos até a falha mecânica no carregamento dinâmico e na aplicação das cargas de flexão no estático até ocorrer a fratura. As análises mostraram que houve diferenças significativas entre os sistemas de implantes sob ambas as condições de carga, revelando que o sistema CM mostrou ciclos mais baixos para falhas e fratura frente às cargas em comparação com as conexões HI e HE. O trabalho concluiu que a conexão CM apresentou menor resistência do que os sistemas de implantes HI e HE.

O assentamento dos abutments cônicos internos é outro fator importante para manutenção da estabilidade das conexões CM e diminuição da

incidência de fraturas de parafusos e componentes protéticos (Mattheos *et al.*, 2016). O teste de força de tração (*pull-out*) tem sido realizado para avaliar o embricamento entre abutment e implante (Kim *et al.*, 2014; Reis *et al.*, 2019). No entanto, o teste mecânico é realizado em abutments de duas peças (parafuso passante), não sendo realizado em abutments de uma peça com porção apical rosqueada por parafusos (Ricciardi Coppedè *et al.*, 2009).

Reis e colaboradores, em 2019, realizaram um estudo *in vitro*, onde seguiram a norma ISO 14801 para aplicação de fadiga estática (30 graus), definindo com este teste a carga a ser utilizada no teste dinâmico em abutments cônicos maciços sem parafusos (5 graus) e abutments de duas peças com parafuso passante (11.5 graus). Após a fadiga dinâmica o teste de *pull-out* mostrou que os abutments de uma peça apresentam um valor bem acima (256 N) comparado com grupo de abutments de parafuso passante (34 N). A menor angulação (5 graus) do sistema que recebeu os abutments inteiros pode ter sido o fator principal para o maior embricamento comparado com os abutment de 11.5 graus.

A simulação de cargas mecânicas e análise de tensões pelo método de análise de elementos finitos (FEA) gera dados relevantes que podem ajudar a minimizar falhas mecânicas, pois vão mostrar as regiões onde acontece maior concentração das tensões (Cehreli *et al.*, 2004; Herbst *et al.*, 2018). As conexões cônicas internas apresentam vantagens, como: menor afrouxamento e fratura do parafuso em comparação com outros tipos de conexões (Carneiro *et al.*, 2016). O *design* dessas conexões internas fornece uma distribuição de tensão mais homogênea ao redor dos implantes, o que levará à diminuição da deformação da crista óssea (Cehreli & Iplikcioglu, 2002). A direção da carga aplicada nas amostras anguladas em 30 graus é escolhida para simular a ação da mastigação, caracterizada por interferência, trauma oclusal, bruxismo e implantes inclinados, seguindo a norma ISO 14801 (Reis *et al.*, 2019). Portanto, os testes mecânicos são importantes, sempre pensando na futura instalação dos implantes em boca (Thomé *et al.*, 2019).

A plataforma *switching* dos implantes cônicos internos também tem sido citada por apresentar características que favorecem a resposta biológica dos

tecidos peri-implantares, como o afastamento do *gap* existente na interface implante-abutment do osso, além da diminuição do desaperto de parafusos (Castro *et al.*, 2014; Macedo *et al.*, 2016). Sendo que, o ângulo da superfície cônica dos implantes cônicos internos também influencia na redução do afrouxamento e fratura dos parafusos devido ao atrito friccional criado por esse tipo de conexão (Merz *et al.*, 2000; Larrucea Verdugo *et al.*, 2014).

Os protocolos de instalação de implantes e carregamento estão mudando (Henry & Raghoobar, 2020). Nos últimos anos existe uma tendência crescente para a instalação de implantes unitários imediatamente após a extração de um dente perdido e realização da provisionalização imediata, apresentando altas taxas de sobrevivência (Zuiderveld *et al.*, 2018).

Diante do exposto, a hipótese deste trabalho é que a força máxima suportada, o afrouxamento dos parafusos e a distribuição de tensão seria semelhante para os três tipos de conexões cônicas internas estudadas. Além de que, os implantes instalados apresentariam sucesso clínico.

OBJETIVOS

2. OBJETIVO GERAL

Avaliar a influência da simulação de cargas mastigatórias na força máxima suportada, afrouxamento de parafusos, *pull-out* e nível de tensão de conexões implante-abutment cônicas internas com 11.5 e 16 graus de angulação.

2.1. Objetivo específico 1: *Influência das cargas mastigatórias na força máxima suportada em conexões cônicas internas – Estudo in vitro.*

Avaliar, por meio de um estudo *in vitro*, se as cargas mastigatórias simuladas teriam influência na força máxima suportada por 3 diferentes tipos de conexão implante-abutment cônicas internas. Um abutment de corpo único (uma peça) (11.5 graus de angulação) e dois abutments de 2 peças (11.5 e 16 graus de angulação) foram estudados.

2.2. Objetivo específico 2: *Influência das cargas mastigatórias no afrouxamento de parafusos, pull-out de abutments de duas peças e distribuição de tensão em conexões cônicas internas. – Estudo in vitro.*

Avaliar, por meio de um estudo *in vitro*, se as cargas mastigatórias simuladas teriam influência nos valores de afrouxamento de parafusos, *pull-out* de abutments de duas peças (parafuso passante) e na distribuição de tensão em conexões cônicas internas. Foram utilizados um abutment de corpo único (uma peça) (11.5 graus de angulação) e dois abutments de 2 peças (11.5 e 16 graus de angulação).

2.3. Objetivo específico 3: *Reabilitação protética de molares inferiores com implantes cônicos internos híbridos: Relato de dois casos.*

Relatar a reabilitação de 2 pacientes com implantes cônicos internos híbridos com 16 graus de angulação instalados imediatamente após a extração de molares inferiores e provisionalização unitária imediata. Foi discutida a utilização de abutments para prótese cimentada e parafusada.

CAPÍTULOS

3. CAPÍTULOS

Serão apresentados nesta sessão três artigos, sendo cada um correspondente a um capítulo.

3.1. Capítulo 1: Artigo 1 - Biomechanical behavior of three different types of internal tapered connections after cyclic and static loading tests: experimental in vitro.

Marcos Boaventura de Moura; Karine Regina Tolesano Loureiro; Lívia Bonjardim Lima; Christian Felippi; Paulo César Simamoto Júnior.

3.2. Capítulo 2: Artigo 2 - Biomechanical behavior of one-piece and two-piece tapered prosthetic abutments with 11.5 and 16 degrees.

Marcos Boaventura de Moura; Karine Regina Tolesano Loureiro; Veridiana Resende Novais; Paulo César Simamoto Júnior.

3.3. Capítulo 3: Artigo 3 – Immediate prosthetic rehabilitation of lower molars with hybrid internal tapered implants: report of two cases.

Marcos Boaventura de Moura; Geninho Thomé; Karine Regina Tolesano Loureiro; Carolina Accorsi Cartelli; Jean Uhlendorf; Paulo César Simamoto Júnior.

3.1. Capítulo 1

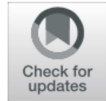
Biomechanical behavior of three different types of internal tapered connections after cyclic and static loading tests: experimental in vitro.

Marcos Boaventura de Moura; Karine Regina Tolesano Loureiro; Livia Bonjardim Lima; Christian Felippi; Paulo César Simamoto Júnior.

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RESEARCH

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Biomechanical behavior of three different types of internal tapered connections after cyclic and static loading tests: experimental in vitro

Marcos Boaventura de Moura^{1*} , Karine Regina Tolesano Loureiro¹, Livia Bonjardim Lima¹, Christian Felippi² and Paulo César Simamoto Júnior¹

Abstract: Background: In the long-term success of a dental implant, the reliability and stability of the implant-abutment interface are important. Studies of maximum force of dental implants with different loading values have been used. This study aims to evaluate the influence of the oblique cyclic loading on the maximum force supported in one-piece and two-piece abutments installed on internal tapered implants.

Findings: Sixty implants and sixty prosthetic abutments were divided into six groups ($n = 10$): G1 and G2 (two-piece abutments with 16°), G3 and G4 (two-piece abutments with 11.5°), and G5 and G6 (one-piece abutments with 11.5°). A 2-Hz cyclic loading was applied to specimens of G2, G4, and G6, with a number of cycles of 2,400,000. All specimens were inclined by 30° from the vertical axis, and a vertical loading was applied over the tapered connections (ISO 14801). Then, the maximum force was tested by applying a static compression load on the specimens of the 6 groups tested (30°) at a rate of 0.5 mm/s. Statistical analysis was performed using the Shapiro-Wilk ($p > 0.05$) and Levene ($p = 0.789$) tests to determine if the data presented homoscedasticity and the Tukey test for multiple comparisons. Tukey test showed that the maximum force supported by G1 and G2 was not affected by the cyclic load, while in G3 and G4 it decreased significantly when subjected to the cyclic load. The G5 and G6 had a significant increase in maximum force supported when subjected to cyclic load.

Conclusions: Cyclic loading influenced the maximum force supported of G4 and G6 but did not influence G2.

Keywords: Biomechanics, Dental implants, Torque

Introduction

Several modifications in implant-abutment design have been made since the 1990s. The screws material and the coefficient of friction between the coupled surfaces were made to reduce the complications of the connection [1]. The mechanical complications of external connections remain a concern in the implant community. To overcome the connection problems, a new concept of internal

connection has been developed [2]. The internal connection has mechanical advantages, such as drastic reduction of screw fractures, distancing the occlusal forces deep into the implant, and protecting the screw from overload [3]. In addition, deep joints in internal connections are more prone to withstand bending forces than the flat joints of external connections. The internal tapered connections appear to be more resistant to screw loosening, abutment movement, and loss of torque, thus being more resistant to fatigue loading [3, 4].

In the internal tapered implant-abutment joints, the fixation and stability are conferred by the frictional resistance resulting from the contact between the tapered

* Correspondence: boaventura.mm@hotmail.com

¹Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlândia, Av. Pará 1720, Bloco 4LB, sala 39, Uberlândia, MG 38405-902, Brazil

Full list of author information is available at the end of the article



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parts of the tapered abutment and implant coupling, not being a function of the screw. The application of axial compressive forces causes the increasing of the frictional resistance resulting from the contact of the tapered coupling parts [5]. Mathematical formulas and finite element (FE) models have shown that more than 86% of the tightening torque and more than 98% of the relaxation torque are balanced by the tapered junction of these systems [5]. The application of the occlusal load is a factor that can lead to loosening of the retention screw and abutment movement [6]. Therefore, *in vitro* mechanical tests have been successfully used for the application of cyclic loads to simulate masticatory forces [4, 7–11].

The geometry of the implant-abutment interface seems to be an influence factor for the transmission of stress around the implant [12]. The use of a tapered connection and abutment with integrated screw (two-piece) is becoming more popular, where the screw and a tapered adjustment are used simultaneously to provide mechanical stability. This type of joint offers high resistance to screw loosening torques and abutment [12].

Several studies have tested dental implants using static loading, while others have used cyclic loading. Failures in the implant-abutment complex usually occur in the application of repeated cyclic loads [13]. Most literature does not mention fatigue as a complex failure mode, influenced by structural design, material properties, and environmental effects. Most of the cycle tests focused on the design of the implant-abutment interface, and only a few studies have addressed the effect of implant diameter on fatigue performance [14]. Although repeated loads may be considered a preponderant cause of failure of dental implants, systematic and qualitative data are quite scarce [14].

The stability of the implant-abutment assembly is critical to the long-term success of implant-supported restorations [8, 9, 11, 12]. Internal tapered connections are known to have good biomechanical stability [11], but further studies remain interesting to be performed, since configurations of different geometries, both implant and abutments, are often launched in the market. Therefore, it is important to study some aspects of these new implant-abutment type configurations, such as biomechanical resistance and stress distribution.

This study evaluated the influence of the oblique cyclic loads on the result of the static loading test (maximum force) in one-piece and two-piece abutments installed on internal tapered implants. Three types of abutments with internal tapered connections were evaluated: A solid one-piece abutment with an apical threaded portion, with internal angle of 11.5° and two two-piece abutments with a transfix screw, one of them with internal angle of 11.5° and another of internal angle of 16°.

The null hypothesis tested was as follows: there is no difference in maximum force supported between implant-abutment assemblies.

Materials and methods

Specimens preparation

Sixty implants with a Morse taper design and 60 prosthetic abutments (Neodent, Curitiba, PR, Brazil) were connected using three different tightening forces: 20 Ncm (G1 and G2), 15 Ncm (G3 and G4), and 32 Ncm (G5 and G6). Each experimental group was formed by ten implants and ten abutments ($n = 10$) for a total of 60 specimens ($n = 60$) (Table 1) (Figs. 1 and 2).

All implants were placed in a cylindrical block made of polyacetal, leaving 3 mm of exposure of these implants, as recommended by ISO 14801 (Fig. 1). A digital prosthetic ratchet (TQ-680, Instrutherm) was used to tightening the prosthetic abutments to the implants.

Dynamic loading test

A cyclic loading was applied to 30 specimens (G2, G4, and G6) using a mechanical cyler for specimens sliding fatigue tests (Electropuls E1000, Instron). To simulate a worst-case condition, specimens were inclined at 30° from the vertical axis for vertical load application, combining bending and torqueing moments on the internal tapered connection. On the cementable part of the abutments was used a semispherical rigid body, the center of which coincided with the center of the free longitudinal axis and was anchored at 11.0 ± 0.5 mm (measured on a line parallel to the longitudinal axis of the implant). A force load of approximately 50 N averaged over each implant-abutment assembly was applied at a frequency of 2 Hz and a temperature of $37^\circ\text{C} \pm 1^\circ\text{C}$. An amount of 2,400,000 cycles were applied on the specimens (Fig. 3).

Static loading test

For the application of the static compression loads in the 60 implant-abutment assemblies in an electrodynamic test system (ElectroPuls E3000, Instron), a semispherical rigid body was used on the abutments and a 30° angulation of the specimens (Fig. 4). A flexural load was applied to the implant-abutment assemblies at a rate of 0.5 mm/s. The bending load acquired by the load cell was plotted on a load versus displacement curve. A computer associated with the machine was programmed to obtain the mechanical behavior of the specimen using a load cell and a load sensor. The test machine was programmed to stop the force test process for a greater displacement of 5.0 mm or an abrupt decrease in the strength of the tested material.

The elastic limit (F_{le}) was represented by the limit point before the plastic or in irreversible limits. Titanium is a material that presents no clear evidence of the

Table 1 Test groups and conditions

Group	Implant	Abutment	Connection type/index/internal angle
1	Titamax GM; Ø3.75/13 mm	Universal Abutment GM exact Ø3.3/6/2.5 mm (two-piece)	Internal tapered/internal hexagon/16°
2	Titamax GM; Ø3.75/13 mm	Universal Abutment GM exact Ø3.3/6/2.5 mm (two-piece)	Internal tapered/internal hexagon/16°
3	Titamax Cortical CM; Ø3.75/13 mm	Universal Abutment CM through screw Ø3.3/6/2.5 mm (two-piece)	Internal tapered/without index/11.5°
4	Titamax Cortical CM; Ø3.75/13 mm	Universal Abutment CM through screw Ø3.3/6/2.5 mm (two-piece)	Internal tapered/without index/11.5°
5	Titamax Cortical CM; Ø3.75/13 mm	Universal Abutment CM Ø3.3/6/2.5 mm (one-piece)	Internal tapered/without index/11.5°
6	Titamax Cortical CM; Ø3.75/13 mm	Universal Abutment CM Ø3.3/6/2.5 mm (one-piece)	Internal tapered/without index/11.5°

exact point between the plastic and elastic limits. The value of the load corresponds to the elastic limit of the material to be tested [15]. In this study, a flexion test was performed by means of static loading on the implant-abutment assemblies. The data curves were generated showing the behavior of the elastic limit for the different loading situations (Fig. 5). The elastic limit values (Fle) were extracted from the measured data using the transition point between linear and non-linear

curves generated from bending tests. The Shapiro-Wilk ($p > 0.05$) and Levene ($p = 0.789$) tests were used to determine whether the cyclic loading application affected the maximum force supported by different implant-abutment assemblies subjected to static loading. For the multiple comparisons between the groups, Tukey test was used. The statistical calculations were conducted in the SPSS 23 program (SPSS Inc., Chicago, IL, EUA), adopting a significance level of 5%.



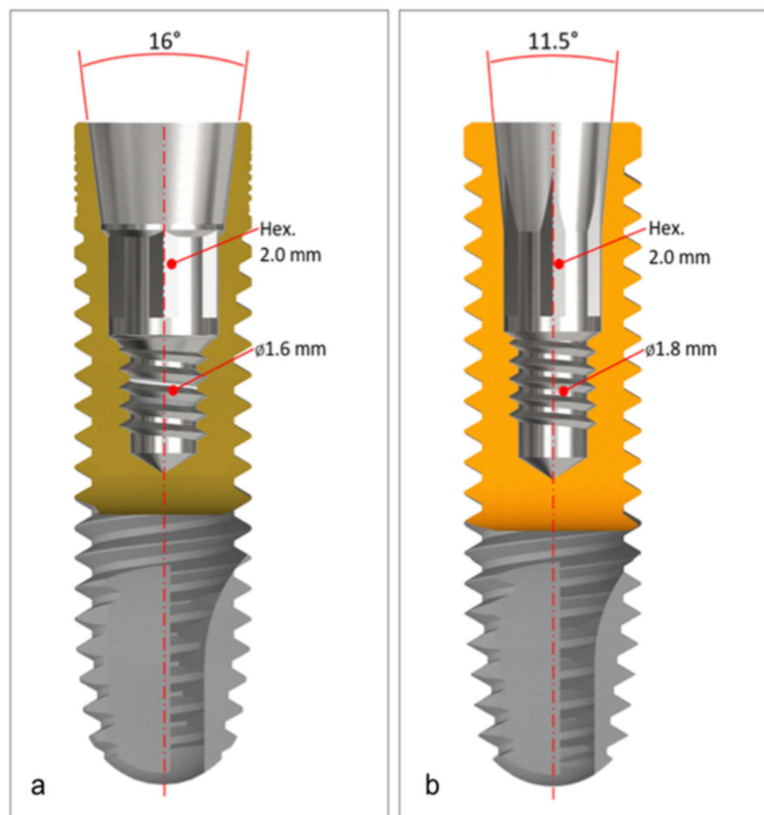


Fig. 2 Different internal angulations of tapered implants used. **a** G1 and G2, Titamax GM implant (16°). **b** G3 to G6, Titamax Cortical CM implant (11.5°)

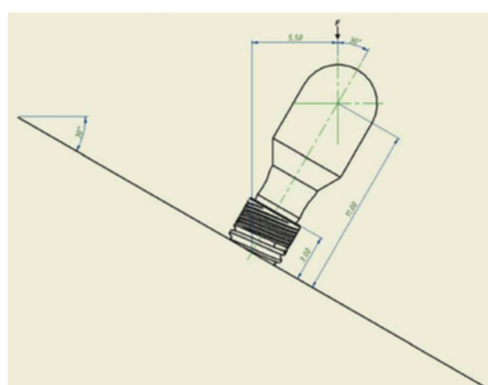
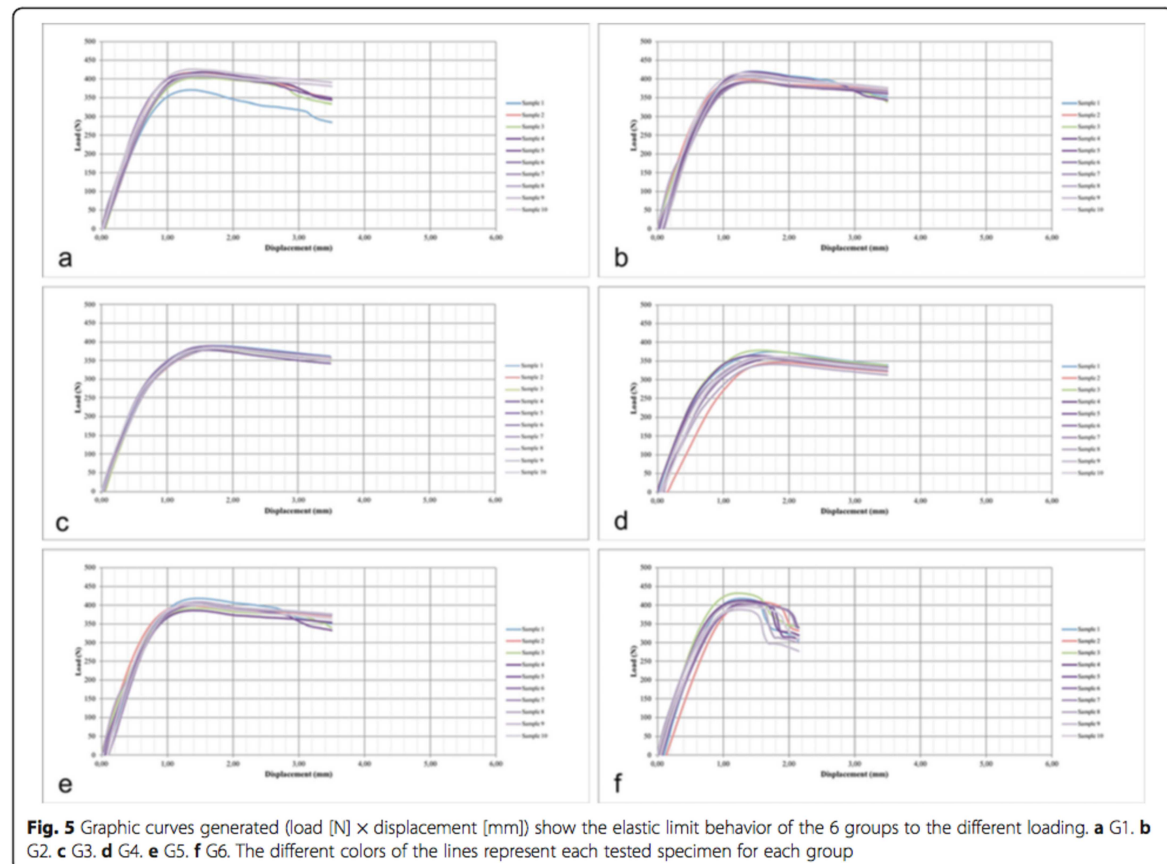


Fig. 3 Schematic of dynamic loading test



Fig. 4 Static loading specimen setup simulating a worst-case condition



Results

No specimen failed after cyclic loading. This study did not evaluate screw loosening after cyclic loading because the specimens were subjected to static loading in sequence to assess the maximum force of each system. The averages and standard deviations of the maximum force (N) after static loading of the implant-abutment assemblies studied are described in Table 2.

Averages followed by distinct capital letters indicate a statistically significant difference between assemblies, considering separately submitted and unloaded specimens (comparisons within each column). Means followed by distinct lowercase letters indicate a statistically significant difference between submitted and unloaded specimens,

Table 2 Means and standard deviations of the maximum force (N) supported by implant-abutment assemblies submitted or not to cyclic loading

Groups	Without cyclic loading	Groups	With cyclic loading
G1	408.28 Aa; (15.09)	G2	404.57 Aa; (11.32)
G3	386.01 Ca; (8.29)	G4	360.88 Bb; (11.18)
G5	402.34 Bb; (8.79)	G6	408.65 Aa; (11.97)

considering each assembly separately (comparisons within each line)

When there was no cyclic loading, the (G1) implant-abutment assembly had maximum force values significantly higher than those found with one-piece abutments (G5) which, in turn, withstood a significantly higher force than that verified for the with two-piece abutments (G3) (Table 2). On the other hand, when there was cyclic loading, although the implant with two-piece abutments (G4) also revealed the lowest values of maximum force, no statistically significant difference was found between the implant-abutment assemblies (G2) and one-piece (G6) (Table 2).

When the interaction between the implant-abutment assemblies (implant system) and the cyclic loading test was evaluated, the Tukey test revealed that for the G1 and G2, the maximum force was not significantly affected by cyclic loading (Table 2). As for the two-piece abutments (G3 and G4), the maximum force was significantly lower when the assemblies were subjected to cyclic loading. In contrast, for the one-piece abutments (G5 and G6), cyclic loading caused a statistically significant increase in maximum force (Table 2).

Discussion

The results of this study do not support the acceptance of the null hypothesis tested. There was a difference in the maximum force supported between the different groups tested. Tukey's test revealed that for the G1 and G2, the maximum force was not influenced by the cyclic load (Table 2). However, for the two-piece abutments (G3 and G4), the maximum force was significantly lower when they were subjected to cyclic loads. In contrast, the one-piece abutments (G5 and G6), the application of cyclic loading caused a statistically significant increase in maximum force (Table 2). Even with different results for maximum force supported, the final values were high. In a clinical situation, all connections would support masticatory forces, except G3 and G4 abutments for molars [16, 17]. Therefore, the dentist can choose which connection suits him best.

The tapered interlock between the tapered surfaces of the prosthetic abutment and the implant is expected to firmly secure the two components together, thus minimizing the importance of screw preload [16]. Therefore, the implant-abutment assemblies of G2, G4, and G6 could be tested by static loading without the need to verify the torques. The number of masticatory cycles simulated approximately 10 years of function [18], which is enough to evaluate the behavior of the abutments. Considering that the ideal is the abutment to be removed only if necessary, this shows that after a long period of simulated cyclic loading, there was no release and/or fracture of screws and no fracture of abutments [11]. However, the two-piece abutments may be more advantageous to the dentist due to their reversibility, as they have the screw that can be loosened more easily. On the other hand, the abutment of a part would be more difficult to remove in a situation of replacement of the prosthesis. Therefore, G1 and G2 would be the best option, since they supported more load compared to the other two-piece abutments.

When a specimen is subjected to any kind of loading, stress is generated. When these loads exceed the material production limit, implant failure may occur in clinical situations [15, 19]. The stress concentration resulting from occlusal forces on the prosthesis that dissipate to the implant/bone interface can lead to microfractures and bone loss around the implants. This factor can also cause implant mobility and fracture [19]. The magnitude of the stresses, the type of implant, and the amount of bone remaining will determine the tissue response. Bone loss caused by overload can probably occur in the crest region surrounding the implants and could favor implant fractures [19]. The test performed in this study simulated a similar loading situation, where the implants were

tested with 3 mm exposure. The best aesthetic results would occur in the 11.5° connections, since they have the largest diameter implant walls and, consequently, a larger platform *switching*, which would favor a better gingival behavior [19].

The design of the internal joints provides a more homogeneous stress distribution around the implants, which will lead to decreased bone crest deformation [15, 20]. In this study, the maximum force of the implant was analyzed in a situation of maximum effort with flexion load applied on the abutment. The direction of load applied on the 30° angled specimens was chosen to simulate chewing action, characterized by interference, occlusal trauma, bruxism, and inclined implants. The type of failure that occurred in the connections was different and may be dependent on the angle or abutment. In two-piece connections, screw elongation and greater tension in the implant walls occur, while in one-piece abutments, fractures occur in the region of the first thread. However, the force resisted by the three connections is greater than that recommended by other authors [21]. Therefore, the three connections showed good results, and the choice is up to the dentist.

Acceptable chewing load values are controversial and variable and have been the subject of studies, but a range between 100 and 286 N [21] for anterior regions and 250 and 392 N [17] for posterior regions are considered. This variation occurs due to different techniques and materials used to measure this load; there is no standardization of these techniques, materials, and no consensus among researchers [22]. In the current study, as shown in Table 2, the three connections tested showed excellent results, with no mechanical failures; only the two-piece abutments of the 11.5° connection (G3 and G4) showed values below what the literature reports [17]; however, the tests show variations [21], and in the mouth we would hardly have an occlusal load in 30°.

The G4 implant-abutment set showed the lowest load values (360.88 N) after dynamic loading but has greater reversibility, while the G6 one-piece abutment showed greater resistance (408.65 N) but does not show the same reversibility. Observing that the two abutments were tested on the same implant (11.5°), it leads to believe that the selection of the abutment is clinically important considering mechanical resistance and reversibility. However, the G2 two-piece abutment would be the most suitable for all regions of the mouth, as this abutment has greater reversibility compared to one-piece and greater resistance (404.57 N) than the G4 two-piece abutment.

The tested implants and abutments have different manufacturing characteristics; the G1 and G2 abutments

have a component self-removal system after the screw is loosened, and the G3 and G4 abutments that showed the worst results may suffer frictional locked at the implant-abutment junction; therefore, it may be interesting in future studies to carry out tests of loosening of screws and pull-out to assess the mechanical stability of the connections. Clinical studies could also test the stability of these connections, taking measurements of the bone level and assessing the success rate and survival of the prostheses in anterior and posterior teeth.

Conclusions

In conclusion, the maximum force supported was influenced by oblique cyclic loading in the implant-abutment assemblies of the G4 and G6 but was not influenced in the G2. Clinically, the G2 connection has good mechanical resistance and reversibility, being more suitable for cemented single rehabilitation.

Abbreviations

G1: Group 1; G2: Group 2; G3: Group 3; G4: Group 4; G5: Group 5; G6: Group 6; GM: Grand Morse; CM: Morse taper; PR: Parana; Ø: Diameter; Fle: Flexural elastic limit

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Authors' contributions

MBM, KRTL, and PCSJ conceived and designed the experiments. MBM, KRTL, LBL, and CF performed the experiments. MBM, CF, and PCSJ analyzed the data. LBL and CF contributed reagents/materials/analysis tools. All authors discussed the results. MBM, LBL, and PCSJ wrote the paper. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

Marcos Boaventura de Moura and Christian Felippi declare that they have competing interests. Both work at the company Neodent, supplier of the products; however, they did not interfere in the result. Karine Regina Tolesano Loureiro, Livia Bonjardim Lima, and Paulo César Simamoto Júnior declare that they have no competing interests.

Author details

¹Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia, Av. Pará 1720, Bloco 4LB, sala 39, Uberlandia, MG 38405-902, Brazil. ²Department of Mechanical Engineering, University Federal of Paraná, Curitiba, PR, Brazil.

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3.2. Capítulo 2

Biomechanical behavior of one-piece and two-piece tapered prosthetic abutments with 11.5 and 16 degrees.

Marcos Boaventura de Moura; Karine Regina Tolesano Loureiro; Veridiana Resende Novais; Paulo Cézar Simamoto Júnior.

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**Biomechanical behavior of one-piece and two-piece tapered prosthetic
abutments with 11.5 and 16 degrees**

Marcos Boaventura de Moura, DDS, MSc, PhD Student¹/ Karine Regina Tolesano Loureiro, DDS, MSc, PhD Student²/ Veridiana Resende Novais, DDS, MSc, PhD³/ Paulo César Simamoto Júnior, DDS, MSc, PhD⁴

¹PhD student, Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia, Uberlandia, MG, Brazil. **Email address:** boaventura.mm@hotmail.com

²PhD student, Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia, Uberlandia, MG, Brazil. **Email address:** karine.t.loureiro@gmail.com

³Professor, Department of Operative Dentistry and Dental Materials, School of Dentistry, Federal University of Uberlandia, Uberlandia, MG, Brazil. **Email address:** veridianaresende@hotmail.com

⁴Professor, Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia, Uberlandia, MG, Brazil. **Email address:** psimamoto@gmail.com

Correspondence to:

Dr Paulo Cézar Simamoto Júnior, Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia (UFU), Av. Pará, 1720, Bloco 4LA sala 4LA-41 - Campus Umuarama, Uberlandia, Minas Gerais, Brazil, phone number: +55(34)3225-8105.

E-mail: psimamoto@gmail.com

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Biomechanical behavior of one-piece and two-piece tapered prosthetic abutments with 11.5 and 16 degrees

Purpose: Investigate the mechanical behavior of one-piece and two-piece prosthetic abutments and the stress level of such abutments after fatigue testing.

Materials and methods: Specimens were divided into 3 groups (n = 10): GM (16 degrees taper angle) and CMt (11.5 degrees taper angle), “Two-piece abutments”, and CMo (11.5 degrees taper angle) “One-piece abutments”. Initially, the abutments were tightened and loosened. The fatigue test was applied to 30 specimens with 15 Hz and 5×10^6 cycles. Subsequently, the abutments were loosened, and a *pull-out* test of the CMt group was performed. A finite element analysis (FEA) was performed on the stress concentration regions. Statistical analysis of the loosening test was performed with 2-way ANOVA and Tukey tests ($p < 0.05$). The results of a *pull-out* test that evaluated the Morse effect was presented for each mean. **Results:** In the loosening test, there was a significant difference within the 3 groups and between the groups with and without fatigue ($p < 0.001$), except between the groups GM and CMt without fatigue ($p = 0.840$). In the *pull-out* test of the CMt group, the sample was frictionally locked only after fatigue (mean = 94.2 N). FEA showed a different stress distribution in the 3 groups, with a higher stress concentration in the abutment body and screw, coronal region and implant body. **Conclusion:** The CMo group presented lower percentages of loosening; however, it also presented a worse stress distribution compared to the GM and CMt groups. The CMt group presented frictional lock after fatigue.

Keywords: biomechanics, finite element analysis, fatigue, implantology, *pull-out*

INTRODUCTION

In internal tapered implant-abutment joints, the fixation and stability are conferred by the frictional resistance resulting from the contact between the tapered parts of the tapered abutment and implant coupling, rather than being a function of the screw. The application of axial compressive forces causes an increase of the frictional resistance resulting from the contact of the tapered coupling parts.¹ Mathematical formulas and finite element (FE) models have shown that more than 86% of the tightening torque and more than 98% of the relaxation torque are balanced by the tapered junction of these systems.¹ The application of occlusal load is a factor that can lead to loosening of the retention screw and abutment movement.²⁻¹¹

The geometry of the implant-abutment interface seems to be an influencing factor for the transmission of stress around the implant.¹²⁻¹⁵ In a study using Morse taper implants with solid one-piece abutments, the crown/implant ratio was evaluated, and it was found that the upper anterior abutments showed an increased loosening tendency. In the posterior regions, the abutments fractured or were loosened.¹⁶ The use of a tapered connection and abutment with an integrated screw (two-piece) is becoming more popular, where the screw and a tapered adjustment are used simultaneously to provide mechanical stability. This type of joint offers high resistance to screw-loosening torque and abutment.¹⁷

The stability of the implant-abutment assembly is critical to the long-term success of implant-supported restorations.^{6-8,10,12} Internally tapered connections are known to have good biomechanical stability,¹⁰ but further studies need to be performed, since in configurations of different geometries, both the implant and abutments are often launched together in the market.^{6,8} Therefore, it is important to study some aspects of these new implant-abutment type configurations, such as biomechanical resistance and stress distribution.^{5,10}

Dental implants are developed with different characteristics, always seeking to obtain acceptable mechanical behavior. The Grand Morse Implant by Neodent has an angulation of the internal tapered portion with 16 degrees (half-angle of 8), the two-piece universal abutment has a self-removable transfixing screw, and no mechanical frictional lock. The Morse taper implant by Neodent has an angulation of the internal tapered portion of 11.5 degrees (half-angle of 5.75). The universal abutments on this implant can be one-piece or two-piece, and the two-piece abutment has a transfixing screw that even after being unscrewed can still have a frictional lock between the internal walls of the implant and the abutment.⁷

The objective of the present study was to investigate the mechanical behavior of 2 two-piece abutments (Grand Morse – 16 degrees taper angle and Morse taper - 11.5 degrees taper angle) and 1 one-piece abutment (Morse taper 11.5 degrees taper angle) before and after cyclic fatigue (dynamic test) in compliance with ISO 14801:2016.¹⁸ The *pull-out* test was used to investigate the Morse effect of 1 two-piece abutment before and after cyclic fatigue. A finite element analysis (FEA) was performed to investigate the stress level of the

mechanically tested prosthetic abutments after cyclic fatigue. The two hypotheses tested were as follows: (1) there would be no difference in the screw loosening values of the tested abutments, and (2) the stress level assemblies of the implant-abutment of the 3 groups would be similar after simulating the fatigue test.

MATERIAL AND METHODS

Sample preparation

The fatigue loading test was performed according to ISO 14801:2016.¹⁸ The free end of the prosthetic abutment was covered with a semispherical rigid body, the center of which coincided with the center of the free longitudinal axis and was anchored at 11.0 ± 0.5 mm (measured on a line parallel to the longitudinal axis of the implant) (Fig 1). Two types of internal tapered implants with different angulations were used (Fig 2). A mechanical test cone component was developed for fatigue application on the implant-abutment groups to transfer the load through the semispherical free edge. The implant-abutment assemblies were divided into the following 3 groups (n = 10): the GM group (Titamax GM implant $\varnothing$ 3.75 x 13 mm and GM Universal Abutment exact 3.3 x 6 x 2.5 mm; Grand Morse, Neodent) with 16 degrees taper angle (half-angle of 8), the CMt group (Titamax Cortical CM implant $\varnothing$ 3.75 x 13 mm and CM Universal Abutment through screw 3.3 x 6 x 2.5 mm; Morse taper, Neodent) with 11.5 degrees taper angle (half-angle of 5.75), and the CMo group (Titamax Cortical CM implant $\varnothing$

3.75 x 13 mm and CM Universal Abutment 3.3 x 6 x 2.5 mm; Morse taper, Neodent) with 11.5 degrees taper angle (half-angle of 5.75) (Table 1).

The sample implants were placed on a rigid base used for 30 degrees angle anchorage, 3.0 mm above the bone (simulating high bone resorption).¹⁸⁻²⁰ A digital prosthetic ratchet (TQ-680, Instrutherm) was used for tightening the prosthetic abutments to the implants.¹⁰ The abutments of the 3 groups were tightened to the manufacturer-recommended torques (GM, 20 Ncm; CMt, 15 Ncm, CMo, 32 Ncm), and after 5 minutes they were loosened, and the values cataloged. Then, another tightening was performed for the mechanical fatigue test.

Fatigue test

The loading force was applied to the surface of the semispherical body by means of a device with a flat surface perpendicular to the direction of loading. The device was not restricted in the transverse direction of the load to avoid reducing the magnitude of the generated bending moment.^{18,19} The dynamic fatigue test was performed using in a wear simulator (Instron E3000 with 3 kN capacity; Instron) with a load frequency of 15 Hz and 5×10^6 cycles, which corresponded to an estimated 5 to 6-year clinical function.^{18,19,21,22} Then, the abutments were loosened, and the values cataloged.

Pull-out test

The *pull-out* test was performed to evaluate the tensile strength (Morse effect) of the Morse taper implants and abutments (CMt Group) with a 11.5 degrees taper

angle at the following two moments: after initial screw loosening and after mechanical fatigue. The tensile strength of the GM and CMO group implants and abutments has not been tested because the GM group (16 degrees taper angle) has abutment self-removal and is easily removed as soon as the screw is loosened; the abutments of the CMO group (11.5 degrees taper angle) are one-piece, with an apical threaded portion.⁷ The implant-abutment assemblies were placed in a mechanical testing machine (MultiTest 2.5 XT; Mecmesin) (Fig 3). The tensile strength (N) required for abutment removal was measured at a speed of 5 mm/min, and the data obtained were analyzed with computer software (Mecmesin).¹⁹ The *pull-out* test was described by the mean and standard deviation (SD) before and after mechanical fatigue.

Finite Element Analysis (FEA)

A numerical analysis of the mechanical testing was performed to evaluate and identify regions of stress concentration in the different implant-abutment assemblies used in this study.²³ The three different types of implant-abutment assemblies used in this study (GM group - Titamax GM implant Ø 3.75 x 13 mm and GM Universal Abutment exact 3.3 x 6 x 2.5 mm; CMt group - Titamax Cortical CM implant Ø 3.75 x 13 mm and CM Universal Abutment through screw 3.3 x 6 x 2.5 mm; CMO group - Titamax Cortical CM implant Ø 3.75 x 13 mm and CM Universal Abutment 3.3 x 6 x 2.5 mm; Neodent) were modeled using FE software (FEMAP with NX Nastran v10.2.0 64-bits, Siemens PLM Software, Texas, United States) to simulate the mechanical test (Fig 4). Computer-aided design (CAD) images developed with Autodesk Inventor Professional 2013 (San Rafael,

California, United States) of the same components used for mechanical testing were provided by the manufacturer (Neodent) of the implants and components and were imported into the FE software. The model components were assumed to be homogeneous, linearly elastic, and isotropic. The material parameters used for the numerical analysis are described in Table 2. The final FE models were a tridimensional mesh incorporating tetrahedra (GM: 91,842 elements and 416,252 nodes; CMt: 72,128 elements and 330,251 nodes; CMo: 72,992 elements and 339,460 nodes).

A layer of element friction between the implant and prosthetic abutment was inserted (0.5 coefficient of friction).^{13,24} An oblique force of 50 N at 30 degrees from the axis of the implants was applied according to ISO 14801 for each tested group in the numerical analysis. Torque relates to the resulting axial preload in the abutment similarly to the screw preload, due to friction forces, were applied between the thread and screw head.¹⁰ The determined axial preload for each group (200 N for GM, 150 N for CMt and 320 N for CMo) was introduced into the model with a layer of elements between the screw body for GM and CMt and the abutment for CMo.

Statistical Analysis

Statistical analysis of the loosening test was performed with 2-way ANOVA and Tukey tests ($p < 0.05$) to compare screw loosening within each group and between groups with and without mechanical fatigue. To perform all loosening analyses, statistical software Sigma Plot (version 12.0; Systat Software Inc.) was used.

RESULTS

No specimen failed after fatigue testing. The results of the loosening test were presented by the percentage (%) of torque, considering the initial torque of 100%. The comparison was performed within each group and between groups with and without mechanical fatigue (Table 3).

Significant difference for the 3 groups occurred in the loosening test when comparing the values with and without fatigue ($p < 0.001$) within each group. When the groups were compared with each other, there was also a significant difference between them ($p < 0.001$), except between groups GM and CMt without fatigue ($p = 0.840$) (Table 3). In the CMt group *pull-out* test, there was no mechanical frictional lock after initial loosening (without fatigue); however, it presented mean and SD of 94.2 ± 12.82 N after fatigue.

FEA showed that the stress distribution was different for the 3 groups. With the load application characteristics on the angled tested implant-abutment assemblies, the stress was more concentrated in the coronal region (collar) and implant body opposite the load application for the 3 groups and the load application side in the CMt and CMo. However, the stress concentration was higher in CMo, where the stress concentration regions near the implant-abutment tapered contact region could also be observed (Fig 5).

The maximum von Mises stress results found for the groups are presented in Table 4. The coronal region of the body of the implants presented the highest stress values found in the 3 groups; however, GM and CMt presented higher values.

DISCUSSION

The null hypotheses for screw loosening and stress level were rejected. There were differences for the values of loosening with and without fatigue and the stress level in the 3 groups studied.

In the abutment screw loosening test, percentages were used to measure the amount of torque loss or gain and to facilitate comparison between groups, since the abutment tightening torque values indicated by the manufacturer are different (15 Ncm to 32 Ncm). Prior to the fatigue test, tightening torques were applied, and the loosening was measured after 5 minutes to serve as an evaluation parameter of a possible influence of fatigue on loosening torques.⁷ According to the literature, the higher the number of fatigue cycles, the greater the initial torque loss value.⁷ The fatigue test was performed at a frequency of 15 Hz and a worst-case condition was simulated leaving the 3 mm implants exposed. These values are in accordance with ISO 14801.^{18,21,22} The number of cycles at each load was set at 5×10^6 to mimic chewing conditions over a period of five to six-years.^{19,21,22}

Failures in the implant body are relevant and concerning; these failures occur due to overloading, which is usually preceded by loosening of the screws, fracture of prostheses or abutment screws and yet it is associated with severe overload.³ In the current study, the reduction in torque of abutments before fatigue (7.8% for GM and 9.67% for CMt) is within acceptable limits according to another study that reports that the deformation and flow of components are

capable of reducing torque applied at 2% to 10% in the first seconds or minutes after tightening.¹¹ Torque loss after the mechanical cycle can be caused by micromovements of the prosthetic components when the screw interface is subjected to external loads. After this stage of "sedimentation effect" or relaxation, surface microroughness of the components may be present, and when micro movements occur due to load incidence, there is a decrease in these surfaces of the components, which results in a decrease of retention screw preload.²³

The loosening test showed higher percentages of torque after fatigue for one-piece abutments of the CMo group (87.34%), while the two-piece abutments of the CMt group had the lowest values (49.19%); however, CMt abutments have mechanical frictional locks believed to help increase stability.⁷ One study reported a torque percentage of 94.6% for one-piece abutments and 70% for two-piece abutments; however, load loading corresponded to 3-4 days of chewing function,⁷ while the current study corresponded to 5 to 6-years.

There are few previous studies about GM system implants, which have been on the market for a short time with a different proposal for resistance improvement. These implants have a 16 degrees taper angle of the internal tapered portion (half-angle of 8) and self-removal of prosthetic components, which facilitates abutment removal in cases of possible fracture of this component or prosthesis. The loosening of these abutments was high without fatigue (92.2%) and decreased after fatigue (67.2%). Past studies suggest that the angle of the implant tapered surface influences the reduction of loosening and fracture of screws.^{13,14} The Morse taper system essentially creates a friction locked.¹³ The

tapered surface joined to another at an angle of less than 16 degrees creates a friction fit that closes mechanically; this adjustment decreases or increases depending on the respective angle changes.¹⁵ In the current study, it was observed that the GM with greater angulation, even without frictional lock, maintained a high torque value after fatigue and still presented the lowest stress in the FEA. Meanwhile, the CM with smaller angulation presented greater frictional lock in the *pull-out* test of the CMt group and in the FEA analysis, which shows the strong connection union and increased stress. The three implant connections studied showed different behaviors, but with good results, and the GM system, which is new on the market, showed promising results. However, animal and human studies are still needed to prove the system effectiveness.

The tapered connections present mechanical characteristics that must be observed. The screw, the tapered abutment portions and the implant act together in the process of insertion and removal of the abutments, both in one-piece and two-piece abutments.¹ The engagement at the implant-abutment junction occurs through the frictional resistance resulting from contact between the tapered coupling sections, and the bolt only helps to guide positioning.¹ In this study, it was not possible to perform the *pull-out* test in the CMo group, because the abutments are one-piece, or for the GM group abutments, which have a component self-removal system. For the two-piece abutments of the CMt group, however, it was possible to loosen the screws and evaluate the *pull-out*.

The *pull-out* test is one of the methods used to evaluate the implant-abutment stability.¹⁹ In this current study, the average *pull-out* value was used for the CMt group (11.5 degrees taper angle), the implant used was 3.75 mm in

diameter and the value presented was 94.2 N. In another study it was used same type implant of 3.75 mm in diameter (11.5 degrees taper angle), and mean *pull-out* values ranged from 27 to 49.6 N.¹⁹ The abutments used in the two studies had different diameter and manufacturing characteristics. The abutment used in the current study has a larger diameter in the cementable part, with a larger load receiving area, which may explain the higher *pull-out* values in the previous study. This test can be used to show whether the results found in the loosening values are a clinical risk or not. Even though there is a higher percentage of loosening of the screw, the mechanical lock can guarantee that the abutment will not come loose, keeping the prosthesis in the mouth.

The key feature of FEA is that it provides a detailed view of the biomechanics inherent in the simulated system.^{10,24} In this study, a 50 N load was used for FEA in the mechanical test for all groups and seemed to be sufficient to evaluate the stress distribution. The stress concentration was different for three groups, regardless of the simulated preload, and the FEA showed that the stress was more concentrated in the coronal region and body of the CMt and CMo implants. However, in the abutments, the stress concentration was located in the region of the body of the CMt and CMo abutments on the load application side and on the screw of the CMo abutments, especially in the threaded region. This behavior suggests that despite the tapered interlock between the tapered surfaces, the screw region still contributes to mechanical stability.^{10,13} This mechanism protects the abutment threads from excessive cyclic functional loading and provides stable retention.¹³

The results of von Mises maximum stress in the coronal region of the implant body were different such that the GM and CMt groups presented higher deformation values compared to CMo (Table 4) (Fig 5), possibly due to the simulated force characteristics in inclined specimens. Increased stresses were also found in the middle of the abutment and implant body in the tapered contact region. Another study used the same implant system (Morse taper 3.5 mm) with a similar one-piece abutment and had a lower von Mises stress than presented here, regardless of the preloads applied (200 N and 320 N).¹⁰ This greater stress can be explained by the 30 degrees inclination of the specimens, while in the previous study, 15 degrees inclination were used. The smaller deformation (von Misses) that occurred in the CMo group may explain why the abutments in this group had the greatest loosening before and after fatigue.

In a previous study, it is suggested to test the prosthetic abutments of one-piece and two-piece from a single manufacturer to compare the torques.¹⁰ In the current study, it was confirmed that the loosening is more stable in the abutment of one-piece compared to two-piece abutments. The design of the internal tapered connection previously showed less torque loss compared to the external connections; the use of coated screws also led to higher torque maintenance compared to uncoated titanium screws.² Further studies could test other implant designs and manufacturers, different internal tapers and implant-abutment connection designs that remain quite commercialized. Clinical studies could also test the stability of different implant-abutment connections using different torque levels, as was performed in a previous study¹⁰, and perform bone level measurements in these connections.

CONCLUSIONS

From the results obtained in this in vitro study, the following conclusions were drawn:

1. From the fatigue test, the internal tapered abutments showed a decrease in the loosening torques compared to the initial loosening without fatigue.
2. One-piece abutments had the highest loosening torque values before and after fatigue, while two-piece abutments in the CMt group had the lowest values. However, the CMt group abutments had a Morse effect in the *pull-out* test, which can be crucial in anchoring an abutment during years of component use in the mouth.
3. The connection of the GM group showed the best behavior in response to stress in the FEA compared to the other groups, which may be an indication of a reduced possibility of fracture occurrence.
4. Additional clinical studies are recommended to investigate whether decreasing the tightening torques of the abutment screws could compromise the stability of the abutment and the implant connection.

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TABLES

Table 1 Test Groups and Conditions

Group	Manufacturer	Implant (Taper angle)	Abutment	Abutment Torque (Ncm)	Connection Type/Index
GM	Neodent	Titamax GM Ø3.75/13 mm (16 degrees)	Universal Abutment GM exact Ø3.3/6/2.5 mm	20	Internal Tapered/Internal Hexagon
CMt	Neodent	Titamax Cortical CM Ø3.75/13 mm (11.5 degrees)	Universal Abutment CM through screw Ø3.3/6/2.5 mm	15	Internal Tapered/ Without Index
CMo	Neodent	Titamax Cortical CM Ø3.75/13 mm (11.5 degrees)	Universal Abutment CM Ø3.3/6/2.5 mm	32	Internal Tapered/ Without Index

Table 2 Material Parameters Used for the Numerical Analyses

Material	E (GPa)	Poisson's ratio
Implants	103	0.361
Abutments	105	0.361
Hemispheric body	105	0.361
Polyacetal	3.1	0.3

Table 3 Statistical comparison of torque loss (%) with and without mechanical fatigue in each group

	GM Group	CMt Group	CMo Group
Without mechanical fatigue	92.2(2.54) Aa	90.33(6.09) Aa	-110.74*(9.92) Ab
With mechanical fatigue	67.2(3.46) Bc	49.19(12.14) Bb	87.34(5.37) Ba

Different letters show statistical difference in the upper case (Intra groups, vertical) and lower case (between groups, horizontal) ($p < 0.05$). Comparison of torque loss (%) without and with mechanical fatigue within each implant-abutment group - Two-piece abutment (GM and CMt Groups) and one-piece (CMo Group);

*Torque gain.

Table 4 Maximum Von Mises Stress Values (MPa) after Simulated Force Application

Groups	Simulated force (50 N)
GM (20 Ncm)	243 MPa
CMt (15 Ncm)	250 Mpa
CMo (32 Ncm)	222 MPa

FIGURES

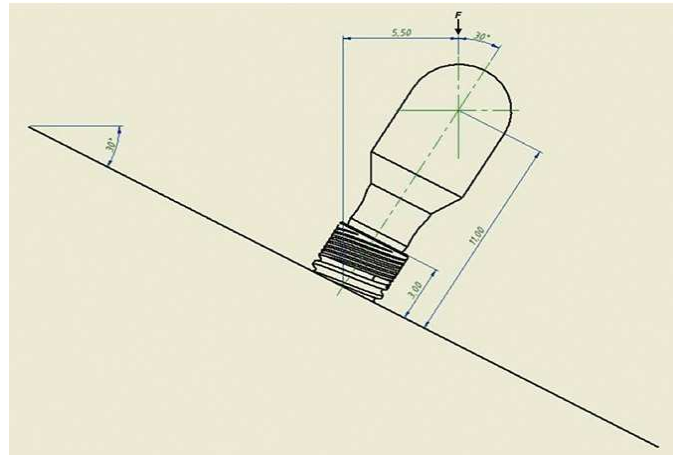


Fig 1 Schematic of fatigue test.

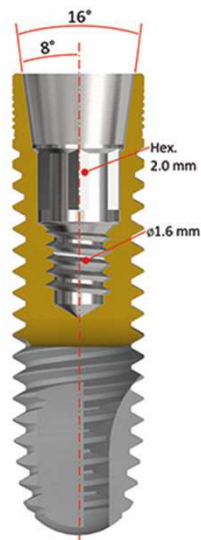


Fig 2a Titamax GM implant – 16 degrees taper angle (half-angle of 8).

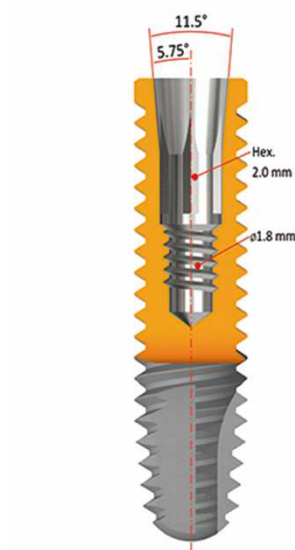


Fig 2b Titamax Cortical CM implant – 11.5 degrees taper angle (half-angle of 5.75).



Fig 3 Assembly implant-abutment placed for the *pull-out* test.

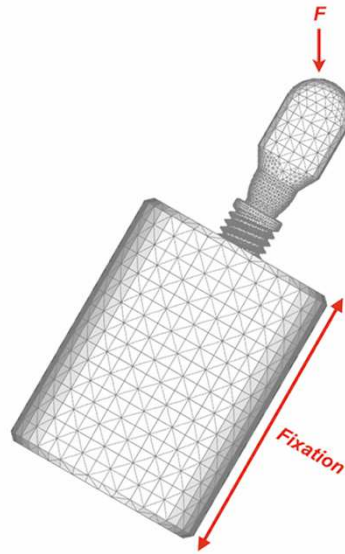


Fig 4 Finite element mesh that simulating the mechanical testing using a vertical load applied to specimens inclined 30 degrees from the vertical axis.

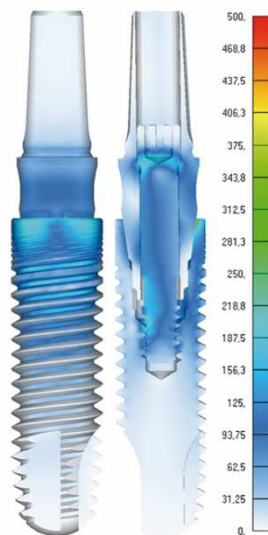


Fig 5a Finite element analysis results of the stress behavior in the prosthetic abutment, implant, coronal region, and screw preload for the 20-Ncm tightening torque under a 50-N load (GM group).

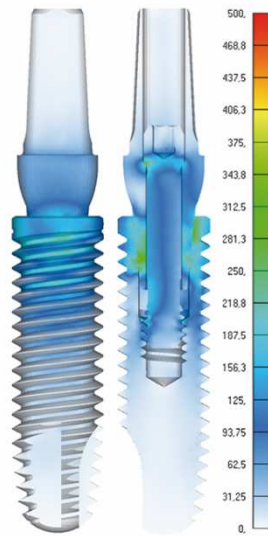


Fig 5b Finite element analysis results of the stress behavior in the prosthetic abutment, implant, coronal region, and screw preload for the 15-Ncm tightening torque under a 50-N load (CMt group).

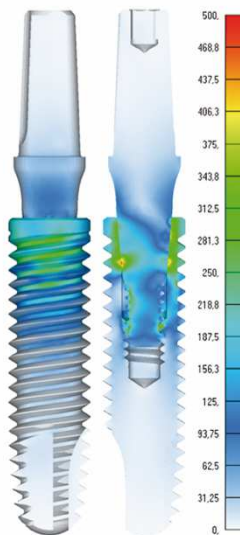


Fig 5c Finite element analysis results of the stress behavior in the prosthetic abutment, implant, coronal region, and screw preload for the 32-Ncm tightening torque under a 50-N load (CMo group).

3.3. Capítulo 3

Immediate prosthetic rehabilitation of lower molar with hybrid internal tapered implants: report of two cases.

Marcos Boaventura de Moura; Geninho Thomé; Karine Regina Tolesano Loureiro; Carolina Accorsi Cartelli; Jean Uhlendorf; Paulo César Simamoto Júnior.

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**Immediate prosthetic rehabilitation of molars with hybrid internal tapered implant:
report of two cases**

**Reabilitação protética imediata de molares inferiores com implantes cônicos
internos híbridos: relato de dois casos**

Marcos Boaventura de Moura¹

<https://orcid.org/0000-0003-2342-2567>

Geninho Thomé²

<https://orcid.org/0000-0003-0209-4058>

Karine Regina Tolesano Loureiro³

<https://orcid.org/0000-0003-0407-8641>

Carolina Accorsi Cartelli⁴

<https://orcid.org/0000-0003-4563-2442>

Jean Uhlendorf⁵

<https://orcid.org/0000-0002-3231-3277>

Paulo César Simamoto Júnior⁶

<https://orcid.org/0000-0001-6087-9721>

¹Doutorando e Mestre em Clínica Odontológica área de Implantodontia e Prótese sobre implante – Universidade Federal de Uberlândia (UFU); Especialista em Implantodontia – São Leopoldo Mandic.

²Doutor em Implantodontia - São Leopoldo Mandic; Professor nos cursos de especialização em Implantodontia e Periodontia – Faculdade ILAPEO.

³Doutoranda e Mestre em Clínica Odontológica área de Implantodontia e Prótese sobre implante – Universidade Federal de Uberlândia (UFU); Especialista em Implantodontia – HD Ensinos Odontológicos – Uberlândia.

⁴Mestre e Especialista em Implantodontia – Faculdade ILAPEO.

⁵Mestre e Especialista em Implantodontia – Faculdade ILAPEO.

⁶Doutor em Clínica Odontológica – Faculdade de Odontologia de Piracicaba (UNICAMP); Professor nas disciplinas de Oclusão, Prótese Fixa e Materiais Dentários – Universidade Federal de Uberlândia (UFU).

Endereço para correspondência

Paulo Cézar Simamoto Júnior

Av. Pará, 1720 – Bloco 4LA, Sala 42, Umuarama

38405-320 – Uberlândia – MG - Brasil.

Telefones: (34) 3225-8108 / (34) 3225-8115

psimamoto@foufu.ufu.br

Immediate prosthetic rehabilitation of molars with hybrid internal tapered implant: report of two cases

ABSTRACT

The immediate rehabilitation of the posterior region of the mandible with dental implants, expands the set of possible actions for the dental surgeon, in the face of tooth loss. The purpose of this study is to describe two cases of single rehabilitation of mandibular molars with hybrid internal tapered implants indicated for immediate loading in post-extraction socket, associated with the maintenance of the prosthetic and peri-implant space. Implants with macrogeometry and surface treatment (Hydrophilic) were used to optimize primary stability, as well as the type of internal connection and prosthetic abutments that allows better accommodation and healing of adjacent tissues, and protection of the bone graft. Different methodologies of surgical guides did not influence the final result. The predictability of associating techniques and components can be observed in the 2-year follow-up. The initial planning combined with the new technologies enable to achieve stable and functional final restorations.

Keywords: Dental implant; Molar; Dental prosthesis; Mouth rehabilitation; Dental restoration temporary.

Reabilitação protética imediata de molares inferiores com implantes cônicos internos híbridos: relato de dois casos

RESUMO

A reabilitação imediata da região posterior da mandíbula com implantes dentários, amplia o conjunto de ações possíveis ao cirurgião dentista, frente as perdas dentárias. O intuito desse estudo é descrever dois casos de reabilitação unitária de molares inferiores com implantes cônicos internos híbridos indicados para carregamento imediato em alvéolos pós-extração, associado a manutenção do espaço protético e peri-implantar. Foram utilizados implantes com macrogeometria e tratamento de superfície que otimizassem a estabilidade primária (Hidrofílicos), bem como o tipo de conexão interna e abutments protéticos que permitisse melhor acomodação e cicatrização dos tecidos adjacentes, e proteção do enxerto ósseo. Diferentes metodologias de guias cirúrgicos não influenciaram o resultado final. A previsibilidade da associação de técnicas e componentes pode ser observada no follow-up de 2 anos. O planejamento inicial aliado às novas tecnologias permitem restaurações finais estáveis e funcionais.

Palavras-chave: Implante dentário; Molar; Prótese dentária; Reabilitação bucal; Restauração dentária temporária.

Introduction

The removal of a tooth root always leads to a set of remodeling processes on the remaining bone, being a limiting factor to achieve adequate aesthetic and functional results.¹⁻³ There are some alternatives for maintaining the available bone framework and preventing the failure of periodontal tissues, such as atraumatic tooth extraction, correct implant placement, bone graft procedures, immediate provisionalization, protecting the peri-implant tissues, maintenance of the prosthetic space, with the absence of lateral force on the implant and infra-occlusion.⁴

Growing expectations of treatments with a shorter duration of time have required significant changes in the macrogeometry of the implants to optimize primary stability, maintenance of peri-implant tissues and predictability of immediate protocols.⁵ In order to place a temporary crown, the recommended primary implant stability torque must be of at least 35 N.cm.⁶ The switching platform of the internal tapered implants provides a stable and resistant connection to achieve long-lasting results.^{7,8}

The use of techniques that use guides illustrate the infinite possibilities that the surgeon has at his disposal in the current scenario of implantology, to achieve the objectives outlined in the planning.⁹ The conventional guided surgery or combined with tomography are fundamental for the excellence of the positioning that goes contribute, with all predictability of hygiene and force distribution, in addition to the exact direction of placement of the implants. "Digital" prosthetic planning generates accurate results, with accuracy very close to what was designed.^{9,10}

This article aimed to present two cases of unitary rehabilitation prosthetic of mandibular molars with hybrid internal tapered implants using different surgical guides.

Case Reports

Case # 1

A 31-year-old man attended the Dental Hospital of the Federal University of Uberlandia (Uberlandia, Brazil) presenting complaints of pain and a coronary fracture of tooth 36, already treated endodontically. Examinations were requested to assess the patient's systemic conditions and radiographic examinations.

On clinical examination, coronary fracture of tooth 36 was observed involving the mesial, distal and lingual surfaces (Figure 1). Radiographic examination revealed an extensive lesion involving the distal surface and the furcation defects of tooth 36, suggestive of endodontic-periodontal lesion (Figure 2). The treatment proposed by the team of professionals was a minimally traumatic extraction of tooth 36 and immediate placement of a hybrid internal tapered implant (hydrophilic) with 16 degrees of internal taper connection and immediate provisionalization with a cemented retained single crown.

The extraction of tooth 36 was performed under local anesthesia, using periotomes and without flaps. A conventional surgical guide made of transparent acrylic resin (Classic, São Paulo/SP, Brazil) was positioned in the mouth and the milling sequence was performed as indicated by the manufacturer (Figure 3).

Then, a Helix Grand Morse (GM) Acqua implant - 4.3 x 11.5 mm (Neodent - Curitiba / PR, Brazil) with a torque of 60 Ncm was placed (Figure 4).

Finally, the gap in the surgical socket was filled with biomaterial of bovine origin (Botiss, Cerabone, Berlin, Germany), which aimed to further improve the emergency profile.

With the lock obtained in the implant placement, it was possible to make a temporary crown in acrylic resin on the selected prosthetic abutment. The cemented prosthesis was chosen, seeking to obtain an emergence and aesthetic profile of the case. A GM Universal Abutment - 4.5 x 6 x 3.5 mm (Neodent) was installed on the implant with a torque of 20 Ncm.

A GM Universal Provisional Cylinder - 4.5 x 6 mm (Neodent) was used to capture the provisional crown (Figure 5). The precise adaptation of the provisional cylinder to the abutment in a click system avoids the use of cement. Therefore, the provisional crown was installed only by compression. Finally, occlusal adjustments were made, relieving contacts that could generate excessive loads (Figures 6 and 7).

After 3 months, the patient returned for definitive rehabilitation. A Click Universal Abutment Impression Coping – 4.5 x 6 mm (Neodent) was placed on the abutment and the impression was made with addition silicone (Hydroxtreme, Coltene, Altstätten, Switzerland) (Figure 8).

The model was scanned on a bench scanner (Ceramill map400, Amann Girrbach, Pforzheim, Germany) to carry out the crown design in the software (Ceramill trusmile, Amann Girrbach) (Figure 9).

With the crown design completed, the data was sent to a milling machine (Ceramill Motion II, Amann Girrbach) to perform crown milling using a ceramic block (Ceramill Zolid fx multilayer, Amann Girrbach). Finally, the zirconia crown was cemented using the dual resin cement RelyX U200 (3M, ESPE, St. Paul, USA).

After 2-years of follow-up, it was possible to observe minimal remodeling of the peri-implant soft tissues and good adaptation of the prosthetic abutments (Figures 10 and 11).

Case # 2

A 34-year-old woman attended the Implantology Department at ILAPEO College (Curitiba, Brazil) with a complaint of coronary fracture of tooth 46, which had been endodontically treated for 6 months. Tests were requested to assess the patient's systemic conditions and radiographic tests.

Upon initial clinical examination, coronary fracture of tooth 46 was observed involving the mesial, distal and lingual surfaces (Figure 12). Radiographic examination revealed a periapical lesion and leakage of endodontic material at the apex of the distal root (Figure 13). The treatment proposed by the professionals was the extraction of tooth 46 and immediate placement of a hybrid internal tapered implant (hydrophilic) with 16 degrees of internal taper and immediate provisionalization with a screwed retained provisional crown. For the ideal positioning of the implant, the use of a prototyped surgical guide (NGS, Neodent) was proposed.

A cone beam computed tomography (CBCT) and virtual models were obtained to perform the virtual surgical planning, using the CoDiagnostiX software (Dental Wings, Chemnitz, Germany). Favorable bone availability was observed for the implant placement. After planning approval, the surgical guide was made using 3D printing (Figure 14). A temporary crown in self-curing acrylic resin was made on the provisional titanium abutment cylinder (Figure 15).

Minimally traumatic extraction of tooth 46 was performed under local anesthesia with the aid of a Dental Extractor (Neodent). With the surgical guide in position (Figure 16), the milling sequence was performed as indicated by the manufacturer, using the NGS (Neodent) technique and a Helix Grand Morse (GM) Acqua implant - 5.0 x 10 mm (Neodent) (Figure 17) was placed with a torque of 60 Ncm. Finally, the bovine biomaterial Botiss Cerabone® (Botiss biomaterials GmbH, Zossen, Germany) was placed in order to improve the emergence profile.

With the lock obtained in the implant placement, it was possible to install a screwed retained provisional single crown. A GM Abutment - 4.8 x 4.5 mm (Neodent) was installed on the implant with a torque of 20 Ncm. The provisional crown was used to capture the Abutment Titanium Coping (Neodent) in the mouth. Finally, the crown was screwed on the abutment and the occlusal adjustments were performed, relieving the contacts that could generate excessive loads during the osseointegration period (Figures 18 and 19).

After 1-year, definitive rehabilitation was performed. An intraoral scan (3Shape, TRIOS, Copenhagen, Denmark) was performed to make a zirconia coping (Figure 20). Then, coping in the mouth, occlusal registration with acrylic resin (Pattern Resin, GC America - Alsip, USA) and transfer molding with addition

silicone (Hydroxtreme, Coltene, Altstätten, Switzerland) were performed. Based on the scanning, it was decided to make a screwed lithium disilicate crown.

After a 2-year follow-up, it was possible to observe minimal remodeling of the peri-implant soft tissues and good adaptation of the crown and prosthetic components (Figures 21 and 22).

The Oral Health Impact Profile 14 (OHIP-14Br)¹¹ was applied to measure the influence of oral health on the well-being of individuals on 2-years follow-up returns after implant placement. OHIP-14 is divided into the following items: functional limitation (items 1 and 2), physical pain (items 3 and 4), psychological discomfort (items 5 and 6), physical disability (items 7 and 8), psychological disability (items 9 and 10), social disability (items 11 and 12) and social disadvantage (items 13 and 14). Questions were scored on a scale: 0 indicates never; 1 rarely; 2 sometimes; 3 constantly and 4 always. The highest score represents the worst quality of life and vice versa. The score of each patient was 4. All but one of the items were answered as “never”, with a score of “0”. Only the item 5, which refers to psychological discomfort and asks the patient about the self-consciousness of their prostheses, was reported as “always”, giving a final score of “4” for each patient.

Discussion and conclusions

The quality of life related to oral health is important when the dentist wants to determine the success of the treatment. Among the reported cases, the highest score obtained with the OHIP-14Br was "4". This indicates less impact of the treatment modality on quality of life. The only negative aspect among patients

was self-awareness about the rehabilitation used. In a previous study, the authors state that this factor is really difficult to determine regardless of the quality of the prosthesis, but it must be considered to determine the success of the treatment.¹² In general, both patients were satisfied with fonetics, aesthetics and function obtained.

Although systematic reviews indicate that there is a slightly higher risk of early implant loss compared to late placement, immediate placement of implants in the extraction sites is assumed to be a reliable treatment option for unitary treatments.^{2,3,13,14} In the present study, an implant with a hydrophilic surface and switching platform was used, which accelerated the osseointegration process and favored the maintenance of peri-implant tissues, in addition to the 16-degree internal angulation of the implant provided greater stability of the implant-abutment junction.

Some authors have reported high survival rates for immediate implant placement in molar regions. These studies suggested that wide diameter implants have better results in the molar region than regular diameter implants.^{4,5} However, in addition to the diameter, the implant macrogeometry and the type of connection are also important for the success of immediate rehabilitation of molars,^{5,15} and in the present study a hybrid implant (cylindrical body and conical apex) was used, with dynamic progressive threads, which allowed for good initial stability.

The use of surgical guides increases the precision of the surgical procedure.¹⁶ The technique simplifies rehabilitation for the surgeon, increasing the probability of obtaining primary stability and predicting the placement of the

implant in an ideal position.^{16,17} In the present study, the conventional and prototyped surgical guides were used for drilling. However, the implant placement was only possible with the prototyped in case # 2. In addition, the primary stability was ideal in both cases. The limitation of the patient's mouth opening must be evaluated, due to the fact that surgery with prototyped guides requires drills of greater lengths.

The technique of immediate provisionalization decreases the collapse of hard and soft tissues, avoiding a second reopening surgery.^{6,18,19} There is scientific evidence stating that immediate provisionalization favors the maintenance of tissue volume by the micro stimulus generated in the bone.^{16,20} It is also suggested to notice that the filling of the socket should be performed whenever a tooth is extracted and has a gap greater than 2 mm.²⁰ In the present study, the use of implants with internal tapered connection and immediate provisionalization were important to minimize bone and tissue remodeling. It was also important to allow and preserve the filling with biomaterial. The prosthetic emergence profile was established by installation the temporary crowns.

Based on currently published controlled studies, there is still a lack of evidence for an ideal protocol for immediate implant placement in the molar region.³⁻⁵ Therefore, the objective of the present study was to evaluate two cases of immediate implant placement in post-extraction sites of molars with immediate provisionalization, which showed excellent results during a 2-year follow-up period.

The immediate placement of hybrid internal tapered implants (hydrophilic), using conventional or tomographic guides and immediate cemented or screwed

retained temporary crowns proved to be a successful treatment protocol for single lower molar substitution, being able to minimize bone and tissue remodeling after 2-years. The overall quality of life related to oral health was good and the patients were satisfied with the treatment received. Prospective clinical studies should be performed, involving biological and prosthetic aspects, but mainly the patients' self-perception, in order to fully understand the immediate rehabilitation of single molars with implants.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on access to patient data and for its publication.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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LEGENDS OF FIGURES



Figure 1. Initial clinical aspect of the case showing the fracture.



Figure 2. Initial periapical radiography of the case.



Figure 3. Surgical guide positioned in the mouth to perform the drilling.

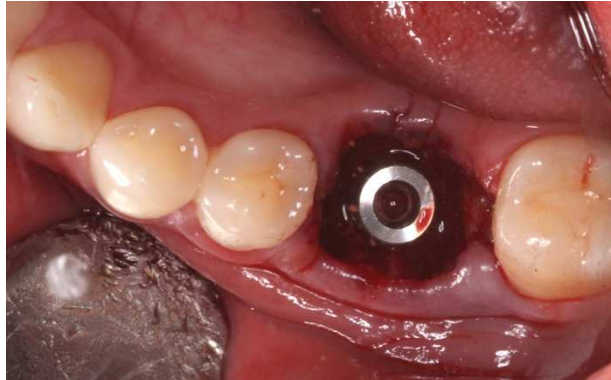


Figure 4. Placement of the 16-degree internal tapered implant in the region of tooth # 36.



Figure 5. Temporary crown performed of acrylic resin in the model.



Figure 6. Immediate postoperative after occlusal adjustment of the provisional crown of tooth # 36.

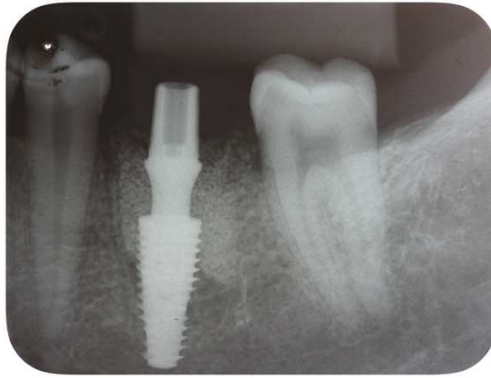


Figure 7. Immediate periapical radiography after installation of the provisional crown of tooth # 36.



Figure 8. Impression of the abutment for making the final crown.

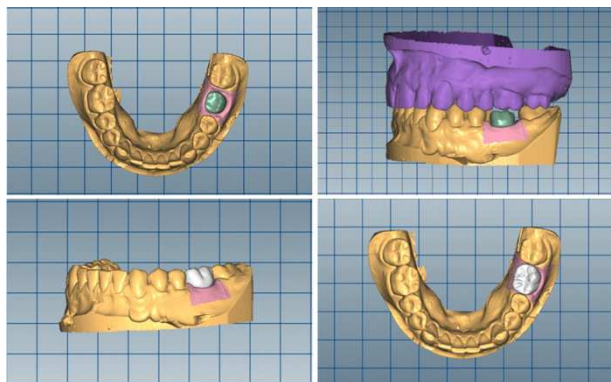


Figure 9. Making the zirconia crown design using Ceramill software after scanning.



Figure 10. Follow-up of 2-years of installation of the zirconia crown.

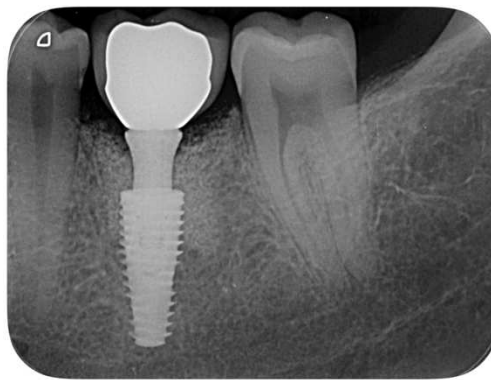


Figure 11. Periapical radiograph 2-years after implant placement.



Figure 12. Initial clinical aspect showing the fracture in occlusal view.



Figure 13. Initial periapical radiograph of the case.



Figure 14. Proof of the prototyped surgical guide on the plaster model.



Figure 15. Proof of the provisional crown on the titanium cylinder.



Figure 16. Surgical guide positioned in the mouth to perform the milling sequence.



Figure 17. Internal tapered implant in the placement key.



Figure 18. Immediate postoperative period for tooth # 46 rehabilitation after occlusal adjustment.



Figure 19. Periapical radiography of the immediate postoperative period after occlusal adjustment of the provisional crown of tooth # 46.

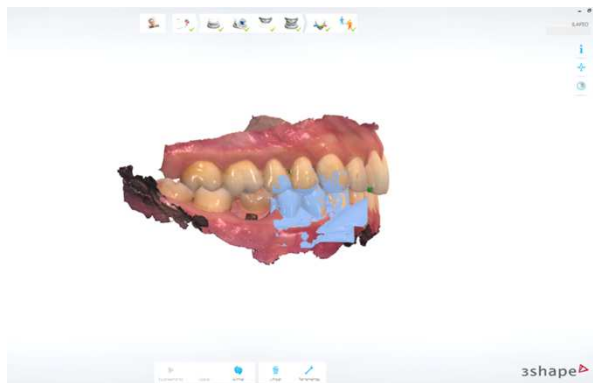


Figure 20. Intraoral scanning for making the zirconia coping.



Figure 21. Clinical aspect 2-years after implant placement.



Figure 22. Periapical radiograph 2-years after implant placement.

CONSIDERAÇÕES FINAIS

4. CONSIDERAÇÕES FINAIS

Considerando as limitações deste estudo, pôde-se concluir que: as cargas mastigatórias que foram simuladas nos estudos tiveram influência na força máxima suportada pelas conexões de implantes com 11.5 graus, mas não influenciaram nas conexões de 16 graus. O afrouxamento de parafusos das conexões testadas e o *pull-out* dos abutments de duas peças de 11.5 graus foram influenciados pelas cargas mastigatórias. A conexão de implantes com 16 graus apresentou uma melhor distribuição de tensões na FEA comparado às conexões de 11.5 graus. A instalação imediata dos implantes cônicos internos de 16 graus usados nesse estudo, com provisionalização imediata e prótese cimentada ou parafusada provou ser um tratamento exitoso para reabilitações unitárias, sendo capaz de minimizar a remodelação óssea e tecidual. Portanto, a correta seleção da conexão de implante e o abutment protético são etapas fundamentais para reabilitações em implantodontia.

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REFERÊNCIAS*

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ANEXOS

ANEXO 1. Normas do periódico do artigo 2.

JOMI

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Number of authors. Authors listed in the byline should be limited to four. Secondary contributors can be acknowledged at the end of the article. (Special circumstances will be considered by the editorial chairman.)

Review/editing of manuscripts.

Manuscripts will be reviewed by the editorial chairman and will be subjected to blind review by the appropriate section editor and editorial staff consultants with expertise in the field that the article encompasses. The publisher reserves the right to edit accepted manuscripts to fit the space available and to ensure conciseness, clarity, and stylistic consistency, subject to the author's final approval.

Adherence to guidelines. Manuscripts that are not prepared in accordance with these guidelines will be returned to the author before review.

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All technology and case reports will appear in online format only. Articles are listed in the issue's Table of Contents and abstracts are printed in the issue. Full text of articles is available online.

MANUSCRIPT PREPARATION

- The journal will follow as much as possible the recommendations of the International Committee of Medical Journal Editors (Vancouver Group) in regard to preparation of manuscripts and authorship (Uniform requirements for manuscripts submitted to biomedical journals. *Ann Intern Med* 1997;126:36–47). See <http://www.icmje.org>

- Manuscripts** should be double-spaced with at least a one-inch margin all around. Number all pages. Do not include author names as headers or footers on each page.
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- Abstract/key words.** The abstract should include a maximum of 350 words. A list of key words should be provided, not to exceed six. Abstracts for basic and clinical research articles must be structured with the following four sections: Purpose, Materials and Methods, Results, and Conclusions. Abstracts of short communications should also be structured but should be a maximum of 250 words. For all other types of articles (ie, literature reviews, technical and case reports), abstracts should not exceed 250 words and need not be structured.
- Article text.** Currently there is no article page limit (within reason).
- Acknowledgments.** Persons who have made substantive contributions to the study can be acknowledged at the end of the article. Also specify grant or other financial support, citing the name of the supporting organization and grant number.
- Legends.** Figure legends should be typed as a group at the end of the manuscript. Detailed legends are encouraged. For photomicrographs, specify original magnification and stain.
- Tables.** Each table should be logically organized, typed on a separate page at the end of the manuscript, and numbered consecutively. Table title and footnotes should be typed on the same page as the table.
- Abbreviations.** The full term for which an abbreviation stands should precede its first use in the text unless it is a standard unit of measurement.
- Trade names.** Generic terms are to be used whenever possible, but trade names and manufacturer name should be included parenthetically at first mention.
- Numbers.** Per SI convention, authors are requested to use decimal points rather than commas for fractional numbers.

REFERENCES

- All references must be cited in the text, numbered in order of appearance.
- The reference list should appear at the end of the article in numeric sequence.
- Do not include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.
- Avoid using abstracts as references.
- Provide complete information for each reference, including names of all authors (up to six). If the reference is to part of a book, also include title of the chapter and names of the book's editor(s).

Journal reference style:

1. Waasdorp J, Reynolds MA. Allogeneic bone onlay grafts for alveolar ridge augmentation: A systematic review. *Int J Oral Maxillofac Implants* 2010;25:525–531.

Book reference style:

1. Wikesjo UME, Hanisch O, Sigurdsson TJ, Caplanis N. Application of rhBMP-2 to alveolar and periodontal defects. In: Lynch SE, Genco RJ, Marx RE (eds). *Tissue Engineering: Applications in Maxillofacial Surgery and Periodontics*. Chicago: Quintessence, 1999:269–286.

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- Images containing type should either be saved as a layered file or provided along with a second file with type removed.
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REPRINTS

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ANEXO 2. Normas do periódico do artigo 3.

INSTRUCTIONS FOR AUTHORS

The Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial (Portuguese Journal of Stomatology, Dental Medicine and Maxillofacial Surgery) is published quarterly, and considers for publication original research reports, clinical reports, short communications and reviews of scientific interest to clinicians and researchers directly or indirectly related with oral health.

All papers are peer-reviewed by members of the journal's editorial board, determining their acceptance for publication. Both authors and reviewers are anonymous during the evaluation of the work submitted.

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May only be made online at <http://www.editorialmanager.com/rpemd> and should include the following elements:

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Signed by all the authors and addressed to the journal's editor-in-chief, stating that the paper is not published or submitted to be published in other journal, and that it will not be submitted elsewhere until the final decision on this submission is taken. The presentation letter should also state that all the authors have read and agree with the submitted version and that, in case of acceptance, transfer the copyright of the paper to the journal. The letter should also contain the manuscript title and refer the contribution of each author to the paper submitted.

According to the "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" the authorship implies a substantial contribution to the manuscript. It is, subsequently, necessary to specify the contribution of each author.

e.g.: John Doe conceived this study and supervised all the aspect of its implementation. Peter Doe collaborated in the experimental protocol and performed the statistic analysis of the data. Charles Doe collected the data and collaborated in the analysis of it. All the authors contributed to the interpretation of the results and to the article revision.

A justification must be presented every time the number of authors exceeds six.

2. Cover page

This page should only contain the title, name and affiliation of each author by the order it should be published (ex: João P. António¹, Pedro Silva², Nuno Pereira¹ – ¹Faculdade de Medicina Dentária de Lisboa, Lisboa, Portugal; ²Faculdade de Medicina Dentária do Porto, Porto, Portugal). The identification of the corresponding author must be given stating name, address, phone number and e-mail.

3. Title

The title of the manuscript should be short (maximum 15 words) and clearly define the subject in question. Should be presented in Portuguese and in English.

4. Authors

Authors should be presented the same way and in the order they will be published (first name middle name, surname). The email and affiliations of each author should be given. **Every type of correspondence between the journal and the authors will be made, exclusively, by e-mail.** Unless otherwise clearly expressed, all correspondence will be sent to the first author.

5. Abstract

Abstracts in **English and Portuguese** should be submitted with a limit of 250 words for research manuscripts and with a limit of 150 words for clinical cases, reviews or brief communications. Abbreviations should not be used.

The abstracts of **original research reports** should contain the main objectives, materials and methods, results and main conclusions. An appropriate heading must precede each section, namely: Objectives; Methods; Results; Conclusions.

The abstracts of **clinical cases** should summarize the problem and the treatment offered.

The abstract of **systematic reviews and brief communications** should present the objective, methods and a brief description of the main topic discussed.

6. Keywords

Keywords (3-10), to allow indexing of the article according to the terminology used in the Medical Index "Medical Subject Headings" (<https://www.ncbi.nlm.nih.gov/mesh>), should be submitted in Portuguese and English.

7. Document with the manuscript

7.1. Presentation:

This document should not have any reference to the author's identity in order to avoid their identification during the reviewing process. All work, including the body of the article, references, figure captions and tables with captions should be formatted double-spaced, Arial font size 12 and left justified. All pages should be numbered, starting at number 1. Margins should be 2.5 cm throughout the document. A page break must be included between each section.

7.2. Body of the article according to the type of work:

a) Research articles – The text should not exceed 2250 words excluding references, legends, and tables. Should be organized into introduction, materials and methods, results, discussion and conclusions. Each section should be organized as follows:

Introduction – Explanation of the problem. Short summary of the relevant literature. Identification of shortcomings and trends in the available studies. Clear description of the paper's purpose at the end, stating the working hypothesis.

Materials and methods – Short summary of the experimental design. Complete description of the materials used (name, manufacturer, lot number and expiration date). Detailed explanation of what was assessed in the work and how it was performed, describing the variables studied, the method for recruiting the sample, sample size, control group used, examiners' calibration method and equipment used in the measurements. The tests used in statistical analysis and statistical significance level set should be mentioned at the end of this section.

Results – Clear and concise description of the results, in the order in which the tests were described in the previous section. Between text, tables and graphs presented there should be no repetition of data. Statistical significant results should be accompanied by their probability value (p).

Discussion – Discussion of the results, relating them to the hypotheses previously presented and with the most relevant literature available.

The limitations of the work should be identified. Target areas for future studies may be suggested.

Conclusions – List concisely the main conclusions to be drawn from the study. The conclusions should be consistent with the objectives and supported by the results.

b) Clinical cases – The text should not exceed 1750 words excluding references, legends, and tables.

Introduction – Conduct a brief review of the literature relevant to the problem in question. Include references to the various methods of treatment available.

Case report – description of the patient (age, gender, etc.), pathology encountered and possible medical or dental history. Brief description of the different treatment methods available. The method of treatment used should be justified and fully described. Results of treatment and length of follow-up should be presented.

Discussion and Conclusions – Remarks on the advantages and disadvantages presented by the method of treatment followed. Present contraindications, if any. If the text is a mere repetition of the previous sections, the Discussion and Conclusions should be omitted.

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Example of the format to follow in references to articles published in journals: Chersoni S, Suppa P, Breschi L, Ferrari M, Tay FR, Pashley DH, et al. Water movement in the hybrid layer after different dentin treatments. Dent Mater. 2004;20:796-803.

Example of the format to follow in references to chapters in books: Marshall SJ. Dental amalgam – Structures and properties. In: Anusavice KJ editor. Phillips' Science of Dental Materials. 10th ed. Philadelphia: WB Saunders Company, 1996. p. 361-85.

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No caso de autoria coletiva, serão incluídos os nomes dos redatores, ou dos responsáveis pelo trabalho, seguido de "e pelo Grupo...", quando todos os membros do grupo são considerados como coautores do trabalho. Se for desejado incluir o nome do grupo, embora nem todos os membros possam ser considerados como coautores, a fórmula usada será mencionar os autores responsáveis, seguido por "em nome do grupo". Em qualquer caso, os nomes e as instituições dos membros do grupo devem ser incluídos num apêndice no final do manuscrito. Os autores serão indicados tanto na primeira ou na página de título e na secção Adicionar / Editar / Remover / Autor. Todos os autores devem declarar que leram e aprovaram o manuscrito e que os requisitos de autoria foram cumpridos. O Jornal declina qualquer responsabilidade sobre eventuais conflitos decorrentes da autoria de obras publicadas no Jornal.

Conflito de interesses

Existe um conflito de interesses quando um autor tem / teve relações financeiras ou pessoais que possam ser inapropriadamente tendenciosas ou influenciar as suas ações. O potencial conflito de interesses existe independentemente do que as partes interessadas consideram que essas relações possam ou não possam ter influenciado o seu julgamento científico. Os autores devem indicar na Carta de Apresentação e na secção de Informações Adicionais do EES, quaisquer relações financeiras ou pessoais que possam ter tido ou possam ter, no momento da escrita ou publicação do artigo, com pessoas ou instituições, e que possam dar origem a um conflito de interesses no que respeita ao artigo que foi submetido para publicação. O que é declarado aparece no jornal impresso.

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Os autores são responsáveis pela obtenção de permissões apropriadas para reproduzir parcialmente material (texto, tabelas ou figuras) de outras publicações. Estas permissões devem ser solicitadas a partir do autor, bem como a partir da editora que publicou esse material. A permissão para publicar é requerida a partir da instituição que financiou a pesquisa.

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Sempre que a aceitação do artigo esteja pendente de alterações a efetuar pelos autores, estas deverão ser realizadas no prazo máximo de 15 dias, para pequenas modificações, ou em 60 dias, no caso de grandes alterações. Após a produção gráfica do artigo, a prova final será enviada ao autor correspondente para aprovação. Este deverá responder por email indicando as alterações necessárias, dentro do prazo limite estabelecido pelo conselho editorial para cumprimento dos prazos da revista. Apenas serão admitidas correções de erros de formatação. A não obtenção de resposta dentro do prazo estabelecido será entendida como sinal de concordância com a versão final apresentada.

Lista de verificação dos documentos a submeter

- Carta de apresentação (obrigatório)
- Página de capa (obrigatório)
- Documento com o corpo do artigo (obrigatório)
- Figuras
- Agradecimentos
- Ficheiros anexos
- Declaração do responsável pelo texto em inglês
- Autorização para divulgação de dados e figuras