SERVIÇO PÚBLICO FEDERAL
MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DE UBERLÂNDIA
FACULDADE DE ODONTOLOGIA
PROGRAMA DE PÓS GRADUAÇÃO

CAROLINA GUIMARÃES CASTRO

Comportamento mecânico e biológico de implante dentário com interface cônica interna

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

Uberlândia, 2015

CAROLINA GUIMARÃES CASTRO

Comportamento mecânico e biológico de implante dentário com interface cônica interna

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

Orientador: Prof. Dr. Flávio Domingues das Neves
Banca Examinadora:
Prof. Dr. Carlos José Soares
Prof. Dr. Gustavo Augusto Seabra Barbosa
Profa. Dra. Karla Zancopé
Prof. Dr. Rodrigo Tiossi

Uberlândia, 2015

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da UFU, MG, Brasil.

C355c
2015

Castro, Carolina Guimarães, 1985-
Comportamento mecânico e biológico de implante dentário com interface cônica interna / Carolina Guimarães Castro. - 2015.
80 f. : il.

Orientador: Flávio Domingues das Neves.
Tese (doutorado) - Universidade Federal de Uberlândia, Programa de Pós-Graduação em Odontologia.
Inclui bibliografia.

1. Odontologia - Teses. 2. Biomecânica - Teses. 3. Implantes dentários - Teses. 4. Carga imediata em implantes dentários - Teses. I. Neves, Flávio Domingues das. II. Universidade Federal de Uberlândia, Programa de Pós-Graduação em Odontologia. III. Título.

CDU: 616.314

AGRADECIMENTOS

Muito obrigada a todos que, de alguma maneira, estiveram ao meu lado durante esta etapa:

Aos meus pais, que sempre serão a base de todas as minhas conquistas.
Ao meu marido e ao meu filho, que me inspiram no dia-a-dia.
Ao meu irmão, que me acompanha e me apoia desde sempre e para sempre.
A minhas amigas Carolina Assaf, Karla Zancopé e Cassiana Piccoli, que, por motivos diferentes, foram muito mais que amigas, me ajudando a continuar.
Aos meus sogros e cunhada e Samuel, por todo apoio e força no dia-a-dia.
A Marina e família, que não consigo encontrar palavras para agradecer o cuidado que têm/tiveram com as pessoas que mais amo no mundo.
As amigas Marina Naves e Anne, que tornaram todas as idas e vindas mais doces e prazerosas.
A minha amiga Fernanda, por todo apoio emocional e profissional no meu dia-a-dia.
A todos meus demais bons amigos que são essenciais para a minha felicidade.
Eu amo vocês!

Ao meu orientador Prof. Flávio Neves, minha gratidão pela oportunidade, confiança e todo aprendizado de muitos anos.
Ao professor Carlos Soares, pela eterna orientação em minhas escolhas.
Ao Dr. Geninho Thomé e ao Alexsander Golin pela oportunidade e confiança de me ausentar do trabalho para buscar aprimoramento.
Aos meus colegas de trabalho, por todo suporte na minha ausência.
A minha querida equipe, por todo o carinho e respeito de sempre.
A todos os professores da banca pela disponibilidade em estar presente e agregar conhecimento a este trabalho.

SUMÁRIO

RESUMO

Este trabalho apresentou como objetivo geral analisar a influência de diferentes fatores na manutenção da interface cônica interna pilar/implante. Os objetivos específicos foram avaliar o efeito do indexador hexagonal interno no selamento microbiológico da interface cone Morse; o efeito do indexador hexagonal interno da resistência mecânica de implantes cone Morse; o efeito do carregamento axial na variação de deformação na região cervical de implantes cone Morse de diferentes diâmetros, por meio de extensometria; o efeito do carregamento axial na deformação cervical e deslizamento do pilar por meio de medição tridimensional; a interface cone Morse antes e após carregamento axial, por meio de microscopia; e a distribuição de tensões em modelos tridimensionais de implantes cone Morse montados com pilares de parafuso passante. De acordo com os resultados obtidos nos estudos pode-se concluir que o diâmetro influenciou a deformação nas paredes externa e interna na região cervical de implantes cone Morse; a presença de indexador protético no fim do cone interno de implantes cone Morse não influenciou na infiltração bacteriana sob carregamento estático; a presença de indexador protético no fim do cone interno de implante cone Morse não reduziu a sua resistência à fratura; um milhão de ciclos de fadiga com carga aplicada axialmente fora do longo eixo do implante não influenciou negativamente a integridade de implante cone Morse montado com componente protético de parafuso passante.

Palavras-chave: implantes cone Morse, comportamento biomecânico, testes biomecânicos.

ABSTRACT

The general aim of this study was to evaluate the conical interface of pilar/implant. The specific aims were to evaluate the influence of hexagonal internal index in the microleakage and mechanical strength of Morse taper implants; the effect of axial loading on the deformation in cervical region of Morse taper implants of different diameters through strain gauge; the effect of axial loading in cervical deformation and sliding of abutment into the implant by tridimensional measurements; the integrity of conical interface before and after dynamic loading by microscopy and microleakage; and the stress distribution in tridimensional finite element models of Morse taper implants assembled with 2 pieces abutment. According to the obtained results, could be concluded that the diameter had influence in the cervical deformation of Morse taper implants; the presence of internal hexagonal index in the end of internal cone of implant didn´t influenced the bacterial microleakage under static loading neither reduced the mechanical strength of implants; one million cycles of vertical and off-center load had no negative influence in Morse taper implant integrity.

Key words: Morse taper implants, biomechanical behavior, biomechanical tests.

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Além da estabilidade mecânica, fatores microbiológicos e oclusais são duas importantes causas para a falha em implantodontia. Enquanto o fator oclusal pode ser controlado cuidadosamente durante o planejamento reabilitador, o fator microbiológico é mais elusivo (Cochran, 1996). Um estudo recente (Koutouzis et al., 2011) indicou que diferentes desenhos de implante podem influenciar o risco potencial para a presença de microorganismos no espaço presente na interface pilar/implante, sob condições de carregamento cíclico. A presença de mediadores químicos e células inflamatórias atuam no processo de osteoclastogênese e, consequentemente, em reabsorção óssea (Broggini et al., 2013). Dessa forma, é importante a busca pela mínima presença de bactérias dentro ou próximo à interface pilar/implante (Dibart et al., 2005).

Diversos autores (Besimo et al., 1999; do Nascimento et al., 2008; do Nascimento et al., 2009; Barbosa et al., 2009; Assenza et al., 2011; Silva-Neto et al., 2012) têm avaliado a microinfiltração em sistemas hexagonais de implantes. Nestes sistemas, onde a manutenção do pilar sobre o implante se dá exclusivamente pela pré-carga do parafuso protético, a qualidade de usinagem e, consequentemente, a adaptação entre as peças é um fator decisivo para os resultados encontrados (Dias et al., 2012). Estes fatores são ainda mais críticos quando se avalia implantes com junção cônica interna.

Há 150 anos, em 1864, o conceito cone Morse foi definido por Stephen A. Morse para componentes rotatórios de máquinas (Hernigou et al., 2013). Há mais de 25 anos, o princípio de interface cônica interna foi trazido para implantodontia dentária (Moser, Nentwig, 1989). Comparando diferentes conexões de implantes, as configurações de junções hexagonal e cônica interna apresentam diferentes princípios mecânicos de funcionamento. A diferença significante é interface cônica, que resulta em excelente estabilidade mecânica por meio de alta pressão de contato e resistência friccional entre as superfícies do implante e do pilar. Como as junções Hexagonais Externas dependem unicamente do parafuso do pilar para fixação e estabilidade da interface pilar/implante (Burguete et al., 1994; Sakaguchi, Borgersen, 1995; Haack et al., 1995; McGlumphy et al., 1998; Bozkaya, Müftü, 2003), o

carregamento axial mastigatório pode resultar no afrouxamento do parafuso e consequente falha do sistema (Schwarz, 2000). Já na interface cônica, fricção e embricamento mecânico na interface cônica entre o pilar e o implante são os princípios básicos para uma conexão eficaz e duradoura (Merz et al., 2000; Bozkaya, Müftü, 2003).

O sistema cone Morse diminui micromovimentações na interface pilar/implante contribuindo para um nível mínimo de inflamação no tecido periimplantar (Dibart et al., 2005) e para menor perda óssea adjacente aos implantes (King et al., 2002). Buscando facilitar a indexação protética do sistema cone Morse, algumas empresas desenvolveram produtos com um indexador geométrico no fim do cone interno do implante (Perriard et al., 2002). Em estudo realizado (Perriard et al., 2002) com o objetivo de comparar a resistência mecânica entre sistemas cone Morse convencionais e indexados, concluiu-se que ambas as conexões são similares quanto à sua resistência mecânica sob teste de flexão do sistema. Ainda sob o ponto de vista mecânico, em estudo clínico recente avaliando 2.549 implantes com interface Cone Morse, após 6 anos em média de função, concluiu-se que a alta estabilidade mecânica desta interface é responsável pela redução significativa de complicações protéticas (Mangano et al., 2011).

Apesar da alta taxa de sucesso do sistema cone Morse, muitas questões ainda vêm motivando estudos científicos. Dentre elas, podemos citar: O implante de menor diâmetro deve ser indicado para regiões de molar? A incorporação do indexador interno compromete o vedamento microbiológico ou a sua resistência mecânica? Existe diferença mecânica entre componentes de corpo único e parafuso passante? Ao longo do tempo o implante sofre deformação devido ao deslizamento do componente dentro do implante? Se sofrer alguma deformação, esta compromete a estabilidade da junção cônica? Qual o papel do parafuso nos componentes de implantes cone Morse? Motivado por estas questões, este estudo propôs-se, por meio da associação de metodologias, analisar a influência de diferentes fatores na manutenção da interface cônica interna pilar/implante.

O entendimento dos princípios biomecânicos que regem as diferentes conexões de implantes permite nortear a predição do comportamento de implantes dentários em diferentes situações clínicas de carregamento. A

associação de diferentes metodologias permite que este entendimento seja buscado de diferentes pontos de vista. Enquanto testes mecânicos experimentais destrutivos mostram a falha de sistemas, a associação de método de elementos finitos, extensometria, microscopia e microinfiltração, permite a avaliação da predição de falhas.

CAPÍTULO 1

Carolina Guimarães Castro, Karla Zancope, Crisnicaw Veríssimo, Carlos José Soares, Flávio Domingues das Neves. Strain analysis of diferente diameter Morse taper implants under overlading compressive conditions. Brazilian Oral Research.

ORIGINAL RESEARCH
Dental Materials

Strain analysis of different diameter Morse taper implants under overloading compressive conditions

Carolina Guimarães CASTRO[a]
Karla ZANCOPÉ[a]
Crisnicaw VERÍSSIMO[b]
Carlos José SOARES[b]
Flávio Domingues das NEVES[a]

[a]Universidade Federal de Uberlândia – UFU, School of Dentistry, Department of Occlusion, Fixed Prostheses, and Dental Materials, Uberlândia, MG, Brazil.

[b]Universidade Federal de Uberlândia – UFU, School of Dentistry, Department of Operative Dentistry and Dental Materials, Uberlândia, MG, Brazil.

Declaration of Interests: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

Corresponding Author:
Flávio Domingues das Neves
E-mail: neves@triang.com.br

DOI: 10.1590/1807-3107BOR-2015.vol29.0028

Submitted: Feb 07, 2014
Accepted for publication: Oct 23, 2014
Last revision: Dec 11, 2014

Abstract: The aim of this study was to evaluate the amount of deformation from compression caused by different diameters of Morse taper implants and the residual deformation after load removal. Thirty Morse taper implants lacking external threads were divided into 3 groups (n = 10) according to their diameter as follows: 3.5 mm, 4.0 mm and 5.0 mm. Two-piece abutments were fixed into the implants, and the samples were subjected to compressive axial loading up to 1500 N of force. During the test, one strain gauge remained fixed to the cervical portion of each implant to measure the strain variation. The strain values were recorded at two different time points: at the maximum load (1500 N) and 60 seconds after load removal. To calculate the strain at the implant/abutment interface, a mathematical formula was applied. Data were analyzed using a one-way Anova and Tukey's test ($\alpha = 0.05$). The 5.0 mm diameter implant showed a significantly lower strain (650.5 μS ± 170.0) than the 4.0 mm group (1170.2 μS ± 374.7) and the 3.5 mm group (1388.1 μS ± 326.6) ($p < 0.001$), regardless of the load presence. The strain values decreased by approximately 50% after removal of the load, regardless of the implant diameter. The 5.0 mm implant showed a significantly lower strain at the implant/abutment interface (943.4 μS ± 504.5) than the 4.0 mm group (1057.4 μS ± 681.3) and the 3.5 mm group (1159.6 μS ± 425.9) ($p < 0.001$). According to the results of this study, the diameter influenced the strain around the internal and external walls of the cervical region of Morse taper implants; all diameters demonstrated clinically acceptable values of strain.

Keywords: Dental Implants; Dental Implant-Abutment Design; Mechanical Phenomena.

Introduction

Excessive occlusal loading or creep deformation of the screw-implant interface could lead to clinical complications such as screw loosening.[1] For a Morse taper implant, the friction at the tapered connection results in a high contact pressure and frictional resistance, causing limited strain that must be absorbed by the abutment screw thread, which differs from the butt joint where the screw alone keeps the abutment connected to the implant.[2,3] This mechanism provides excellent biological and mechanical stability and unusual prosthetic versatility;[4] in fact, the prosthetic versatility is similar to that of a hexagonal implant. A total of 2,549 Morse taper connection implants that were placed in 893 patients were evaluated, and the incidence of abutment loosening was 0.37% for

single tooth replacements alone. No complications were observed at the implant-abutment interface for fixed partial prostheses and fixed full-arch prostheses, and no abutment fractures were observed.[5] Contact and friction play crucial roles in the mechanical behavior of the individual parts of a system, including oral implants.[3,6]

The tapered interference fit relies on a large contact pressure and the resulting frictional resistance in the mating region of the implant–abutment interface to provide a secure connection.[7] In general, interference fit implants have a hub and shaft that connect to each other and do not require a third member, such as a key, pin, bolt, or screw. The connection allows for load transmission due to the frictional forces between the mating surfaces where the shaft has a slightly larger diameter than the hub. The dependent characteristics of the interference fit, including the pullout/insertion forces and the stress distribution in the members, depend on the taper angle, contact length, inner and outer diameters of the members, depth of insertion, material properties and coefficient of friction.[7]

Clinically, straight and wide diameter implants are used in many clinical scenarios, including the use of single dental implants. In Morse taper implants, the measurements of the internal cone are the same, regardless of the implant diameter. In straight diameter implants, the thickness of the titanium wall around the implants is thinner than in wide diameter implants. These implants, submitted to overload, especially in single implants in patients who have an oral dysfunction, could cause a design modification of the Morse taper implant.

Even though Morse taper implants with different outer diameters have the same internal conical diameter, there is a difference in the thickness of the cervical portions of different implants. In this context, there is a lack of research evaluating the effect of axial compressive loading on dimensional changes in the cervical portion of Morse taper implants with different diameters. The strain around these walls can be measured using strain gauge analysis, which is a non-destructive method.

Therefore, the aim of this study was to evaluate the deformation caused by compression in different diameters of Morse taper implants and the residual deformation after removal of the load. The hypothesis in this study was that the diameter of Morse taper implants affects the strain variation of the cervical portion.

Methodology

Samples

Thirty Morse taper implants (Neodent, Curitiba, Brazil) were divided into the following 3 groups (n = 10) according to implant diameter: 3.5 mm, 4.0 mm and 5.0 mm. The implants (Figure 1) were produced specifically for this study and lacked external threads to allow for strain gauge fixation (Figure 2). Each implant was fixed to a two-piece abutment (Universal Post Exact, Neodent, Curitiba, Brazil). The material characteristics are described in Table 1.

Strain Gauge Test

A strain gauge (PA-06-040AB-120 LEN, Excel Sensores, São Paulo, Brazil) was attached to each specimen with cyanoacrylate glue (Super Bonder Loctite, Rocky Hill, USA). The gauge was a custom

Figure 1. Implants that were specifically produced without external threads to allow for strain gauge fixation.

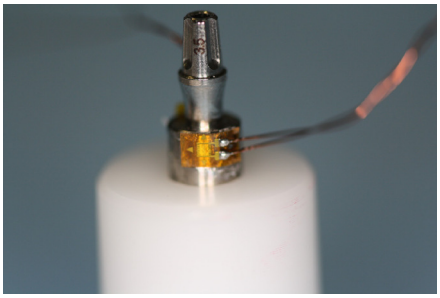

Figure 2. Strain gauge fixation.

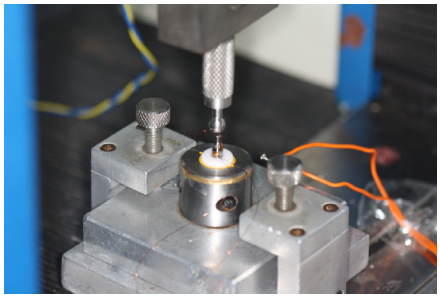

Figure 3. Axial loading was applied.

Table 1. Description of materials.

Material	Description	Quantity (un)
Cylindrical Morse taper Implant	3.5 x 13 mm	10
Cylindrical Morse taper Implant	4.0 x 13 mm	10
Cylindrical Morse taper Implant	5.0 x 13 mm	10
Universal CM Post (two pieces)	3.3 x 4 x 3.5 mm	30

apparatus that enabled specimen stabilization and was placed perpendicular to the long axis of the implant. The strain gauge wires were connected to the data acquisition device (ADS0500IP Lynx, São Paulo, Brazil).

The abutments were placed using 15 N-cm of insertion torque, as recommended by the manufacturer. The samples were subjected to axial compressive loading (Figure 3) with a crosshead speed of 0.5 mm/min in a universal testing machine (EMIC, 2000DL, São José dos Pinhais, Brazil) until 1500 N of loading force was reached. The 1500 N loading force was based on pilot studies that defined the load value required to cause physical deformation of the 5.0 mm diameter Morse taper implant under axial compressive loading. A study reported an occlusal force in an axial direction on implants of up to 847 N for men and 595 N for women with normal occlusion.[8] Compared to the occlusal loading measured in patients with a normal dentition, the absence of a periodontal ligament may lead to occlusal overloading and implant failure due to the inability to distribute occlusal forces, axial transmission of these forces, and the absence of periodontal proprioceptors.

Therefore, we simulated overloaded forces to test the mechanical characteristic of this implant under this condition. A study[9] reported that the mean voluntary maximal bite force for male bruxers was 1009 ± 290 N. During all tests, the strain gauge remained fixed on the cervical portion of the implant to measure the strain variation. The load was removed and the strain measurement was recorded for 60 seconds.

Data were evaluated statistically with a one-way ANOVA ($\alpha = 0.05$) and Tukey's test. The strain in a thick cylinder with internal pressure was higher in the interior of the canal and decreased as it approached the external surface. To measure the internal strain, the following formula[10] was applied: $\varepsilon A/B = (b^2 + a^2) / 2a^2$, where $\varepsilon A/B$ = the relationship between the internal strain and external strain, a = internal canal radius, and b = external canal radius.

Results

The implant diameter significantly influenced the strain around the cervical region of the Morse taper implants. The implant with a 5.0 mm diameter had significantly lower strain than the other groups ($p < 0.001$), regardless of the presence of a load (Table 2). The strain values had a 50% reduction after load removal, regardless of the implant diameter. Figure 4 illustrates the strain pattern for all implant diameters according to the loading variation (0 - 1500 - 0 N).

The internal strain values, calculated according to the formula $\varepsilon A/B = (b^2 + a^2) / 2a^2$ are summarized in Table 3. The implant diameter significantly influenced the internal strain around the cervical region of the Morse taper implants. The 5.0 mm

Table 2. The mean strain values (μS) ± SDs and statistical categories defined via Tukey's test (n = 10) for the three different implant diameters.

Strain criteria	Ø implant		
	5.0 mm	4.0 mm	3.5 mm
Strain at maximum load (1500 N)	650.5 ± 170.0^{A}	1170.2 ± 374.7^{B}	1388.1 ± 326.6^{B}
Residual Strain (after removing the load)	377.5 ± 106.9^{A}	594.3 ± 173.6^{B}	784.4 ± 128.8^{C}

Means followed by the different letters indicate statistically significant differences at 5% compared to the similar values from different diameter implants.

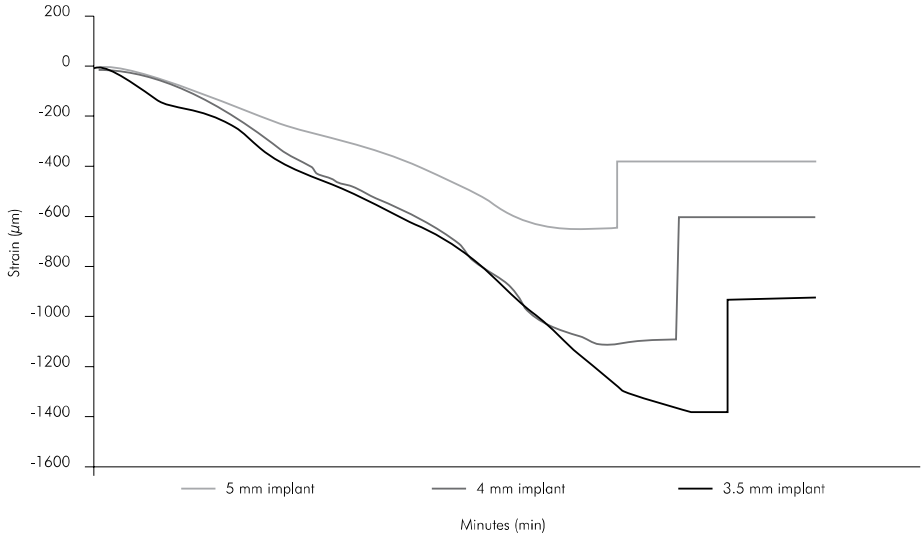

Figure 4. Strain (μS) curve obtained for the three different implant diameters according to the loading 0 - 1500 - 0 N.

Table 3. The mean internal strain values (μS) ± SDs and statistical categories defined via Tukey's test (n = 10) according to the formula $\varepsilon A/B = (b^2 + a^2) / 2a^2$.

Strain criteria	Ø implant		
	5.0 mm	4.0 mm	3.5 mm
Strain at maximum load (1500 N)	1625.7 ± 590.2^{A}	2082 ± 758.5^{B}	2052.2 ± 681.3^{B}
Residual Strain (after removing the load)	943.4 ± 504.5^{A}	1057.4 ± 681.3^{B}	1159.6 ± 425.9^{C}

Means followed by the different letters indicate statistically significant differences at 5% compared to similar values from different diameter implants.

diameter implants showed a significantly lower strain than the other groups ($p < 0.001$).

Discussion

The hypothesis was accepted. The diameter influenced the strain around the internal and external wall of the cervical region of Morse taper implants. The two-piece abutment allowed us to slide the abutment into the internal conical surface of the implant during axial loading.

When the implant diameters were analyzed, there was a 20% reduction in the strain between

the 5.0 and 4.0 mm implants and a 12.5% reduction in the strain between the 4.0 and 3.5 mm implants. These percentage differences most likely caused the significant difference between the 5.0 and 4.0 mm groups, as well as the statistical similarity between the 4.0 mm and 3.5 mm groups. When the residual internal strains were analyzed, there were significant differences between all groups, which could be due to the thickness variations between the cervical portions of single implants and the presence of the abutment, which worked as a wedge by forcing the entrance of a single implant. Clinically, masticatory forces could result in a residual stress over implants, resulting in plastic deformation. The response of bone tissue around these implants must be investigated. However, this extreme situation occurs in only male bruxers over years of dysfunction. Further studies with cyclic loading to simulate this dysfunction are still needed.

As illustrated in Figure 4, there were differences in the observed values with the same strain variation behavior between the three implant diameters. This could be explained by the differences between the radii of all groups. In this study, the internal radius for all implant diameters was 1.25 mm, and the external radius varied between 1.75, 2.00 and 2.50 mm for the 3.5, 4.0 and 5.0 mm diameter implants, respectively. Under the same loading condition, the 3.5 mm implant experienced approximately twice the strain variation compared to the 5.0 mm implant. All of the diameters had a residual strain of approximately 50% of the maximum strain observed at a 1500 N loading force.

Table 2 summarizes the residual strain values resulting from abutment placement. Because residual strain did not dissipate with time, it increased the risk of the plastic deformation. The same proportion of twice the strain variation between the 3.5 and 5.0 mm groups was observed for the residual strain values. Based on these results, when placing single implants in male bruxers, a 5 mm diameter implant would be clinically better than a 3.5 mm or 4 mm diameter implant in the posterior regions of mouth for the following two reasons: the molar regions primarily receive axial loads[11] and posterior regions are subjected to the highest forces in the arch.[12] However, the authors of the present study emphasize that different implant diameters demonstrate clinically acceptable values of strain during normal function according to Figure 4.

The strain gauge analysis was chosen because it is a non-destructive methodology that provides a better understanding of the biomechanical behavior of dental implants.[13,14] An advantage of the present strain gauge study is the large number of samples per group (n = 10), increasing the reliability of the data. Finite element analysis (FEA) could complement the present findings. In another study,[7] the FEA and closed-form results were in agreement regarding the contact pressure in the tapered interference connection of dental implants, showing that the contact pressure increased at the locations where the implant was thicker, which provided more resistance to deformation. Further studies are still needed to understand the influence of preloading on Morse taper abutments and how much stress would be transmitted to the surrounding bone from different implant diameters.

Conclusion

According to the results in this study, the diameter influenced the strain around the internal and external walls of the cervical region of Morse taper implants. All diameters demonstrated clinically acceptable values of strain.

Acknowledgements

The authors would like to thank Neodent, NEPRO Research Group, CPBio and *Fundação de Amparo a Pesquisa do Estado de Minas Gerais* – FAPEMIG for their contributions to this research. The authors declare that they have no conflicts of interest.

References

1. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res. 2000;11(Suppl 1):156-8.
2. Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants. 1995 Sep-Oct;10(5):529-36.
3. Merz BR, Hunenbart S, Belser UC. Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. Int J Oral Maxillofac Implants. 2000 Jul-Aug;15(4):519-26.
4. Nentwig GH. Ankylos implant system: concept and clinical application. J Oral Implantol. 2004;30(3):171-7.
5. Mangano C, Mangano F, Shibli JA, Tettamanti L, Figliuzzi M, D'Avila S, et al. Prospective evaluation of 2,549 Morse taper connection implants: 1- to 6-year data. J Periodontol. 2011 Jan;82(1):52-61.
6. Sakaguchi RL, Borgersen SE. Nonlinear contact analysis of preload in dental implant screws. Int J Oral Maxillofac Implants. 1995 May-Jun;10(3):295-302.
7. Bozkaya D, Müftü S. Mechanics of the tapered interference fit in dental implants. J Biomech. 2003 Nov;36(11):1649-58.
8. Waltimo A, Könönen M. Maximal bite force and its association with signs and symptoms of craniomandibular disorders in young Finnish non-patients. Acta Odontol Scand. 1995 Aug;53(4):254-8.
9. Cosme DC, Baldisserotto SM, Canabarro SA, Shinkai RS. Bruxism and voluntary maximal bite force in young dentate adults. Int J Prosthodont. 2005 Jul-Aug;18(4):328-32.
10. Popov EP. Mechanics of materials. 2nd ed. Englewood Cliffs: Prentice-Hall Inc.; 1976. 590 p.
11. Castro CG, Santana FR, Roscoe MG, Simamoto Jr PC, Santos-Filho PC, Soares CJ. Fracture resistance and mode of failure of various types of root filled teeth. Int Endod J. 2012 Sep;45(9):840-7.
12. Fernandes AS, Dessai GS. Factors affecting the fracture resistance of post-core reconstructed teeth: a review. Int J Prosthodont. 2001 Jul-Aug;14(4):355-63.
13. Vasconcellos DK, Özcan M, Maziero Volpato CÂ, Bottino MA, Yener ES. Strain gauge analysis of the effect of porcelain firing simulation on the prosthetic misfit of implant-supported frameworks. Implant Dent. 2012 Jun;21(3):225-9.
14. Harel N, Eshkol-Yogev I, Piek D, Livne S, Lavi D, Ormianer Z. Bone microstrain values of 1-piece and 2-piece implants subjected to mechanical loading. Implant Dent. 2013 Jun;22(3):277-81.

CAPÍTULO 2

Carolina Guimarães Castro, Caio César Dias Resende, Leandro Maruki Pereira, Marcel Santana Prudente, Karla Zancope, Letícia Resende Davi, Mário Paulo Amante Penatti, Flávio Domingues das Neves. Influence of the prosthetic index into Morse taper implants on bacterial microleakage: Bacterial microleakage into Morse taper implants. Implant Dentistry.

De: "Jefferson, Heather" <Heather.Jefferson@wolterskluwer.com>
Assunto: ID-D-15-00058
Data: 27 de abril de 2015 09:01:33 BRT
Para: "neves@triang.com.br" <neves@triang.com.br>
Cc: Luanne Webber <softbyte@beeline-online.net>

Dear Flávio Domingues das Neves,

Re: ID-D-15-00058 (Influence of the prosthetic index into Morse taper implants on bacterial microleakage: Bacterial microleakage into Morse taper implants)

Your article has been accepted for publication in Implant Dentistry. I will manage its production through all of its stages from now until publication. Please contact me should any queries arise.

Your article will be edited for grammar and journal style. Once the copy-editing has been completed, I will send you an e-mail to notify you of the approximate date that you will receive page proofs of your article.

If there are any queries relating to your article, they will be sent to you with your page proof. Please answer them as promptly as possible so that delay to the process can be avoided.

Once your article has published, you will be contacted via email to order reprints.

If your submission contains 5 or more color figures, please follow these instructions. If you want your figures to appear in color, please complete the color form and return it to me within 7 days. Prompt return of the signed form, even if you choose to decline color, will avoid delays in publication. If I do not hear from you within one week, I will assume that you are happy to have your figures printed in black and white only.

As a special benefit reserved for LWW authors, you are invited to take advantage of our "Author Loyalty Program," which entitles you to a 10% discount on selected LWW titles. To learn more, click here.

I look forward to working with you.

Sincerely,
Heather Jefferson
Production Editor
Medical Research
Wolters Kluwer
351 W. Camden St.
Baltimore, MD 21201
Heather.Jefferson@wolterskluwer.com

Influence of the prosthetic index into Morse taper implants on bacterial microleakage: Bacterial microleakage into Morse taper implants

AUTHORS: Caio César Dias Resende, DDS*, Carolina Guimarães Castro, DDS, MSc**, Leandro Maruki Pereira, DDS***, Marcel Santana Prudente, DDS, MSc#, Karla Zancope, DDS, PhD##, Letícia Resende Davi, DDS, PhD###, Mário Paulo Amante Penatti, BDS, PhD+, Flávio Domingues das Neves, DDS, PhD++

ABSTRACT (167 WORDS)

Purpose: Evaluate the influence of Morse taper implant index on microleakage.

Materials & methods: Thirty implants and abutments were divided into three groups (n=10): CM1 (universal post and implant without index), CM2 (universal post and implant with index) and CM3 (abutment and implant with index). To evaluate the microleakage from the implant inner part, the implants were inoculated with *Streptococcus sanguinis* solution at a 0.5 McFarland and incubated for 7 days at 37ºC in Eppendorf tubes with sterile broth. To evaluate the microleakage into the inner part of implant, these were inoculated with sterile Schaedler broth and immersed in a *Fusobacterium nucleatum* solution at a 0.5 McFarland. The samples were incubated for 30 days in an anaerobic chamber.

Results: Nine samples of each group of the first methodology no presented bacterial contamination. No samples of the second methodology demonstrated turbidity of the broth.

Conclusion: The presence of the prosthetic internal index had no influence on bacterial microleakage of Morse taper implants under static conditions, for both methodologies.

KEY WORDS: microbiology; prosthodontics; periodontology.

* Private practice, Uberlândia, MG, Brazil.

** PhD student, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

*** Master student, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

PhD student, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

Post doctoral fellow, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

Associate Professor, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

+ Associate Professor, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG, Brazil.

++ Associate professor, Clinical Analysis Technical Course, Technical School of Health, Federal University of Uberlândia, Uberlândia, MG, Brazil.

Reprint requests and correspondence to: Flávio Domingues das Neves, DDS, PhD, Av. Pará, 1720, Bloco 4L, Anexo A, sala 4LA-42, Campus Umuarama, CEP: 38405-320, Uberlândia, Minas Gerais, Brazil

E-mail: neves@triang.com.br Phone: +55-34-3218-2222 Fax: +55-34-3218-2626

The misfit of implant/abutment (I/A) interface is responsible for biological complications.[1] The microscopic space caused by the misfit between implant and prosthetic component (microgap) facilitates the infiltration of fluids and macromolecules from tissue fluids and saliva, facilitating bacterial invasion and proliferation.[2-5] These infiltrations cause the bone loss in most cases, even in patients with good oral hygiene.[6]

The level of contamination varies or depends not only on the precision of fit, but also on the degree of the applied micromovement and torque. The incidence of loads and unscrewing of the prosthetic abutment can increase infiltration, whereas optimal adaptation, minimal micromovement and exceptional prosthetic and occlusal planning are factors that can prevent or minimize microleakage.[7,8] The conical interface of Morse taper implants presents high contact area which decreases the gap, contributing to an efficient I/A sealing.[9-11] This high precision contact could prevent the I/A micromotion,[12] decrease the screw tightening, microleakage, peri-implantar inflammation and maintain the bone around of the implant,[13,14] compared to Brånemark System implants.

Nowadays, to improve implant installation, some manufactures have added an internal index on Morse taper implants and the positive index to the abutments facilitates the position in the prosthetic steps.[15] However, abutments without index could be assembled to the implants with index. In these conditions, the higher empty space between implant and abutment could facilitate the microleakage and bacterial colonization.

The literature demonstrated several methodologies to evaluate the bacterial leakage along the implant-abutment interface.[1,10,16-18] Bacterial infiltration has been evaluated in a two-way path,

not only from inside the screw role to the outside (I/E)[1,5,12,18-21] but also inward from the outer part of the implant (E/I).[10,17,20,22]

Nonetheless, all methods have several critical points that can either lead to false positive or false negative results.[18] Considering the false negative results, the diminished internal empty space that support the lowest volume of bacteria, could represent death of this microorganism.[18] Therefore, the increase of this internal space implant with index could generate favorable conditions.

The aim of this in vitro study was to evaluate the presence of prosthetic index assembled to the Morse taper implants by bacterial microleakage test in static conditions. The hypothesis of this study was that the presence of the internal index would not influence the results of microleakage.

MATERIALS AND METHODS

Implant System

Thirty conical Morse taper implants (Alvim CM, 3.5mm x 13.0mm, Neodent, Curitiba, Brazil) and 20 abutments solid CM Universal Post without index (ø 4.5 x 4.0 x 1.5mm, Neodent) and 10 abutments CM exact universal post (ø 4.5 x 4.0 x 1.5mm, Neodent) with passing bolt were selected to this study. The implants and abutments were divided in three groups (n=10): CM1: Morse taper implants without prosthetic index and solid CM Universal Post without index; CM2: Morse taper implants with prosthetic index and solid CM Universal Post without index; CM3: Morse taper implants with prosthetic index and CM exact universal post with passing bolt.

Pilot Tests

First, a pilot test was conducted to evaluate the amount of bacterial suspension that could be inoculated to the inner part of implants, without overflow of broth. To determine the volume of inoculation, the Inventor software assembled the CAD of implant and abutment and calculated the empty space between abutments and implant (Fig. 1). After that, dye and bacterial suspension were used to evaluate the optimal volume of suspension into the implant, without overflow.

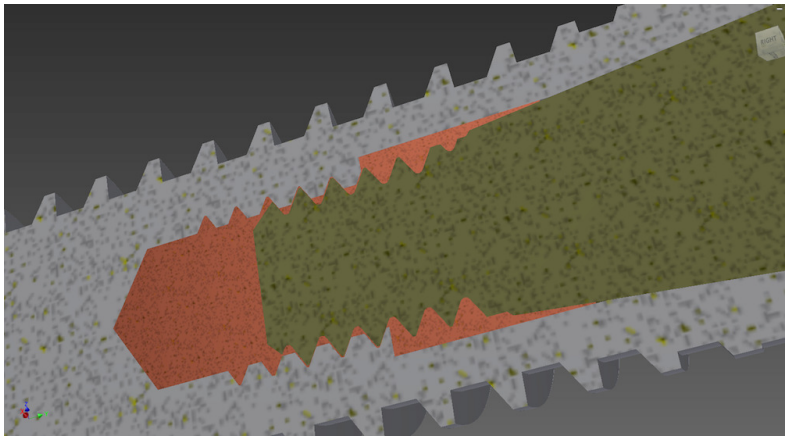

Figure 1 - Inventor software - CAD images of implant and abutment. Before the pilot test, to determine the volume of inoculation, the software assembled the CAD of implant and abutment and calculated the empty space between abutments and implant.

The implants were stabilized in a metallic holder and inoculated the solution of 1% toluidine blue with an automatic pipette (0.5-10µL, LABMATE+, HT-High Tech Laboratories). Then, the abutments were assembled and tightened according to the manufacturer instructions (Fig. 2). The overflow was verified by visual inspection or by absorbent paper. (Fig. 3) The test using the dye was repeated until recorded the optimal volume.

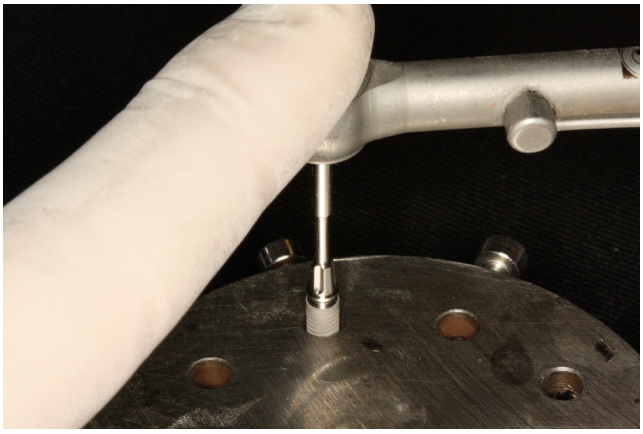

Figure 2 - The abutments were assembled and tightened according to the manufacturer instructions, stabilized in a metallic holder and inoculated the solution with an automatic pipette.

Figure 3 - The overflow was verified by visual inspection or by absorbent paper. The test using the dye was repeated until recorded the optimal volume, without visual overflow.

The final volume was confirmed with the dipped tests using the *Streptococcus sanguinis* ATCC 10556 cultivated in Schaedler agar plate. One colony was collected and cultivated in tubes containing BHI broth, which was stored at 37ºC and 1 atm for 24 hours. All of the instruments were autoclaved (Prismatec, Itu, Brazil) at 121°C at 15 psi for 15 minutes. At the inner of the implants was inoculated the volume found in test pilot with dye under laminar flow hood (VECO, Campinas, Brazil). The abutments were carefully connected to the implants and sterile forceps were used to the dip the implant in a sterile solution broth for 30 seconds (Fig. 4). This solution was incubated to verify the overflow of bacterial solution at the tightening procedure. After 3 days of incubation, the broth was evaluated through turbimetry test.

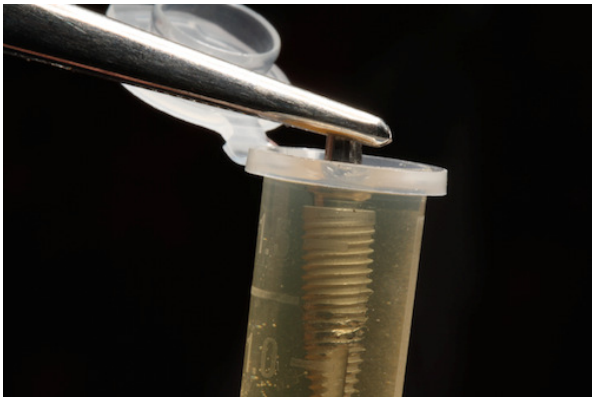

Figure 4 - The abutments were carefully connected to the implants and sterile forceps were used to the dip the implant in a sterile solution broth for 30 seconds. This solution was incubated to verify the overflow of bacterial solution at the tightening procedure.

Microleakage test

The microleakage test was recorded with two methodologies: leakage from the inner part of the implant and leakage into the inner part of the implant. For the first test, the *Streptococcus sanguinis* ATCC 10556 were used and for the second test the *Fusobacterium nucleatum* suspension were cultivated in Schaedler broth (Biolife, Milan, Italy) supplemented with 0.1% hemin and 0.1% menadione in an anaerobic chamber (Whitley DG250, Don Whitley Scientific, England) for 2 days at 37℃. A standard bacterial suspension dilution of 0.5 McFarland (corresponding to approximately $3x10^8$ colony forming unit/mL – CFU/mL) was prepared and using at the microleakage test.

Leakage from the inner part of the implant:

The implants were removed from their packaging under sterile conditions and placed at metallic holder. The inner part of the implant was inoculated with 0.5µL of *Streptococcus Sanguinis* suspension for the groups CM1 and CM3. The group CM2 was inoculated with 2.1µL. The abutments were carefully connected to the implants and tightened with 32 Ncm for the group CM1 and CM2 and 15 Ncm for the group CM3, according to the manufacturer's instructions. The assemblies were immersed at 590mL of sterile Schaedler broth and incubated at 37℃ for 7 days in anaerobic chamber.

Leakage into the inner part of the implant:

The implants were removed from their packaging under sterile conditions and placed at metallic holder. The inner part of the implant was inoculated with 0.5µL to group CM1 and CM3 and 2.1µL of sterile BHI broth. The abutments were carefully connected to the implants and tightened, according to the manufacturer's instructions. The assemblies were immersed in 590µL of *Fusobacterium nucleatum* suspension and incubated at 37℃ for 3 days.

Statistical Analysis

The statistical analysis of the leakage was performed using the chi-square test, in which statistically significant differences were accepted as $P < 0.05$.

RESULTS

The volume recorded by the Inventor Software was: CM1 3.1 µL, CM2 6.0 µL, CM3 4.7 µL. To confirm the volume internal capacity the pilot test was done with dye. The results were: CM1 1.9µL, CM2 2.4µL and CM3 4.4µL. Following, the pilot test made with bacteria found the final volumes: CM1 and CM3 0.5µL and CM2 2.1µL. The final volume of each group was inoculated at the corresponding implant and the microleakage were recorded.

In methodology 1, nine samples of group CM1, CM2 and CM3 showed no contamination by I/A interface (Table 1).

In methodology 2, no contamination occurred in the evaluated period.

There were no statistical differences, by chi-square ($P = 0,236$) between the results on both methodologies.

Table 1 – Positive and negative results of control test and microleakage from the inner part of implant.

	CM1		CM2		CM3	
	Control test	Microleakage	Control test	Microleakage	Control test	Microleakage
1	-	-	-	-	-	-
2	-	-	-	-	-	+
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	+	-	-	-	-
10	-	-	-	+	-	-
Total	0	1	0	1	0	1

DISCUSSION

The results obtained support the hypothesis that the presences of the internal index not influence the results of microleakage. Then the presence of the internal prosthetic index at hexagonal shape and the range of the volume in the inner surface not influence the sealing of Morse taper.

The current research obtained the volume of inoculation first by the software analysis followed by the dye test and the bacterial test. The pilot test was important to determine the real volume of inner implants. Several studies did not report the standardization of inoculated volume into the implant.[9,10,13,23,24] The steps described in the present study could guide the researches to enhance the optimal volume for microleakage test.

Two bacteria were used in the microleakage tests. First, to analyze the microleakage from the inner surface, the *Streptococcus sanguinis* were used and into the inner surface of the implant the *Fusobacterium nucleatum* were used.[9,22,25,26] Both bacteria could be found in the oral cavity and related to the peri-implantite. However, the *Streptococcus sanguinis* are able to connect with titanium and present dimensions from 0.5 to 1µm.[9]

Bacterial infiltration may occur in a two-way path, into and from inner part of implants.[17-19] This marginal leakage in implants is facilitated by the presence of microgaps between the implant and the abutment components of the assembled system. Even so, some studies argued that this gap is about 1 to 49 µm, depending on the system.[1] These gaps may be further widened when subject to chewing forces, facilitating bacterial proliferation and consequently inflammatory cells that lead to bone loss around I/A.[18] This contributes in part to malodor and infection of the periimplant tissue.[25] Morse taper abutments are less prone to bacterial leakage at the implant/abutment interface, because of the large contact surface with the implant, forming a frictional locking.[9-11,27]

The microleakage can be varied when different torque levels are used.[3,4] Gross et al[5] showed that when the torque increased from 10 to the maximum torque recommended by the manufacture, microleakage decreased significantly for all systems tested. So, the present study followed the manufacturer's recommendations to prevent possible variations that could interfere with the results.

This study was evaluated in static conditions, but the gap can be altered by mechanical loading,[7,13] a factor that might favor a higher influx of bacteria into the interface. Koutouzis et

al[13] utilized an in vitro dynamic loading model to assess the potential risk for invasion of oral microorganisms. The specimens were immersed in a bacterial solution of *Escherichia coli* and loaded with 500,000 cycles of 15 N in a wear simulator. They found that the leakage of microorganisms through the interface was greater when a load was applied.

The time of incubation, elevated bacterial concentrations and environments with limited conditions of oxygenation and nutrition could represent extremely adverse conditions for bacterial reproduction and survival.[18] These environments could lead to false-negative results because of the death of these microorganisms into the implants. Hence, longer monitoring periods (over 7 days) must be avoided.[18] Some studies[16,25] evaluated the microleakage through the implant/abutment interface for 7 days, as the present study. Furthermore, it is important to note that, at the end of the monitoring periods, the implants must be reopened to verify bacterial viability (Fig. 5).

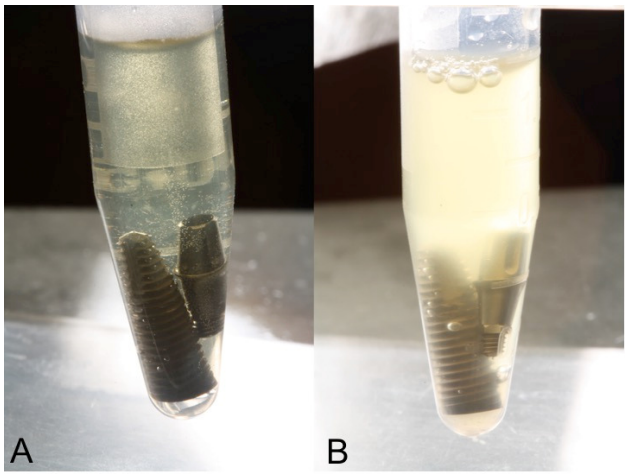

Figure 5 - Sample exhibiting turbity, to verify bacterial viability after the test period. A- No turbity; B – Turbity.

Micro Ct Images was done to evaluated different volumes founded with prosthetic index (Fig. 6). The final volume was inoculated using Barium solution contrast and these images showed that

both methodologies couldn´t remove all air of internal cavity during inoculation, explaining the difference between the software volume and the tested volume.

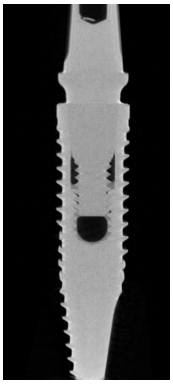

Figure 6 - Micro-CT image was done to evaluated different volumes founded with prosthetic index. The final volume was inoculated using Barium solution contrast and these images showed that both methodologies couldn´t remove all air of internal cavity during inoculation, explaining the difference between the software volume and the tested volume.

To ensure the precision of the inoculation, the dental surveyor was adapted with pipette holder. The presence of the guide to avoid the false positive results could be done. In this case, the diameter of the inner implant surface was 3 mm and the manual inoculation could insert the bacteria closed to the implant interface.

The present study showed lower rate of microleakage between implant-abutment interfaces using the turbidity test. Similar results were recorded in recent researches.[9,18,22,23,28,29] This fact confirms that the Morse taper junction sealing is efficient even with prosthetic index changes. According to the literature, the current implant systems cannot completely prevent microbial leakage and bacterial colonization of the inner part of the implants and may result in soft tissue inflammation, constituting a risk to the stability and clinical success of the implants.

To simulate the mouth conditions, future research could be realize considering the dynamic conditions on the microleakage. Procedures that simulate chewing may contribute to the sealing

of the interface or the presence of oblique loading could generate higher gaps facilitating the microleakage.

CONCLUSION

Within the limitations of this study, it can be concluded that the presence of the prosthetic internal index had no influence on bacterial microleakage of Morse taper implants under static conditions, for both methodologies.

ACKNOWLEDGEMENTS

The authors wish to thanks Neodent (Curitiba, Brazil), the Technical School of Dentistry, the School of Dentistry of Federal University of Uberlândia – CPBio and CNPQ for its contribution to this research.

DISCLOSURE

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the paper.

REFERENCES

1. Jansen VK, Conrads G, Richter EJ, et al. Microbial leakage and marginal fit of the implant-abutment interface. *Int J Oral Maxillofac Implants.* 1997;12:527-540.

2. Alves DC, Carvalho PS, Martinez EF, et al. In vitro microbiological analysis of bacterial seal at the implant-abutment interface using two Morse taper implant models*. Braz Dent J.* 2014;25:48-53.

3. D'Ercole S, Tripodi D, Ravera L, et al. Bacterial leakage in Morse cone internal connection implants using different torque values: an in vitro study. *Implant Dent.* 2014;23:175-179.

4. Larrucea Verdugo C, Jaramillo Nunez G, et al. Microleakage of the prosthetic abutment/implant interface with internal and external connection: In vitro study*. Clin Oral Implants Res*. 2013;25:1078-1083.

5. Gross M, Abramovich I, Weiss EI, et al. Microleakage at the abutment-implant interface of osseointegrated implants: a comparative study. *Int J Oral Maxillofac Implants.* 1999;14:94-100.

6. Rimondini L, Marin C, Brunella F, et al. Internal contamination of a 2-component implant system after occlusal loading and provisionally luted reconstruction with or without a washer device. *J Periodontol.* 2001;72:1652-1657.

7. Steinebrunner L, Wolfart S, Bossmann K, et al. In vitro evaluation of bacterial leakage along the implant-abutment interface of different implant systems. *Int J Oral Maxillofac Implants.* 2005;20:875-881.

8. Harder S, Quabius ES, Ossenkop L, et al. Assessment of lipopolysaccharide microleakage at conical implant-abutment connections. *Clin Oral Investig.* 2012;16:1377-1384.

9. Aloise JP, Curcio R, Laporta MZ, et al. Microbial leakage through the implant-abutment interface of Morse taper implants in vitro*. Clin Oral Implants Res.* 2010;21:328-335.

10. Dibart S, Warbington M, Su MF, et al. In vitro evaluation of the implant-abutment bacterial seal: the locking taper system. *Int J Oral Maxillofac Implants.* 2005;20:732-737.

11. King GN, Hermann JS, Schoolfield JD, et al. Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: a radiographic study in the canine mandible. *J Periodontol.* 2002;73:1111-1117.

12. Coelho PG, Sudack P, Suzuki M, et al. In vitro evaluation of the implant abutment connection sealing capability of different implant systems. *J Oral Rehabil.* 2008;35:917-924.

13. Koutouzis T, Wallet S, Calderon N, et al. Bacterial colonization of the implant-abutment interface using an in vitro dynamic loading model. *J Periodontol.* 2011;82:613-618.

14. Hermann JS, Schoolfield JD, Schenk RK, et al. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. *J Periodontol.* 2001;72:1372-1383.

15. Perriard J, Wiskott WA, Mellal A, et al. Fatigue resistance of ITI implant-abutment connectors -- a comparison of the standard cone with a novel internally keyed design. *Clin Oral Implants Res.* 2002;13:542-549.

16. Harder S, Dimaczek B, Acil Y, et al. Molecular leakage at implant-abutment connection--in vitro investigation of tightness of internal conical implant-abutment connections against endotoxin penetration. *Clin Oral Investig.* 2010;14:427-432.

17. Ricomini Filho AP, Fernandes FS, Straioto FG, et al. Preload loss and bacterial penetration on different implant-abutment connection systems. *Braz Dent J.* 2010;21:123-129.

18. Silva-Neto JP, Prudente MS, Carneiro Tde A, et al. Micro-leakage at the implant-abutment interface with different tightening torques in vitro. *J Appl Oral Sci.* 2012;20:581-587.

19. Barbosa RE, do Nascimento C, Issa JP, et al. Bacterial culture and DNA Checkerboard for the detection of internal contamination in dental implants. *J Prosthodont.* 2009;18:376-381.

20. Besimo CE, Guindy JS, Lewetag D, et al. Prevention of bacterial leakage into and from prefabricated screw-retained crowns on implants in vitro. *Int J Oral Maxillofac Implants.* 1999;14:654-660.

21. do Nascimento C, Barbosa RE, Issa JP, et al. Bacterial leakage along the implant-abutment interface of premachined or cast components. *Int J Oral Maxillofac Surg.* 2008;37:177-180.

22. do Nascimento C, Barbosa RE, Issa JP, et al. Use of checkerboard DNA-DNA hybridization to evaluate the internal contamination of dental implants and comparison of bacterial leakage with cast or pre-machined abutments. *Clin Oral Implants Res.* 2009;20:571-577.

23. Assenza B, Tripodi D, Scarano A, et al. Bacterial leakage in implants with different implant-abutment connections: an in vitro study. *J Periodontol. 2011*;83:491-497.

24. Dias EC, Bisognin ED, Harari ND, et al. Evaluation of implant-abutment microgap and bacterial leakage in five external-hex implant systems: an in vitro study. *Int J Oral Maxillofac Implants.* 2012;27:346-351.

25. do Nascimento C, Miani PK, Pedrazzi V, et al. Bacterial leakage along the implant-abutment interface: culture and DNA Checkerboard hybridization analyses. *Clin Oral Implants Res.* 2012;23:1168-1172.

26. Baggi L, Di Girolamo M, Mirisola C, et al. Microbiological evaluation of bacterial and mycotic seal in implant systems with different implant-abutment interfaces and closing torque values. *Implant Dent* 22:344-350.

27. Teixeira W, Ribeiro RF, Sato S, et al. Microleakage into and from two-stage implants: an in vitro comparative study*. Int J Oral Maxillofac Implants.* 2011;26:56-62.

28. Deconto MA, Salvoni AD, Wassall T, et al. In vitro microbiological bacterial seal analysis of the implant/abutment connection in Morse taper implants: a comparative study between 2 abutments. *Implant Dent.* 2010;19:158-166.

29. Tripodi D, Vantaggiato G, Scarano A, et al. An in vitro investigation concerning the bacterial leakage at implants with internal hexagon and Morse taper implant-abutment connections. *Implant Dent.* 2012;21:335-339.

CAPÍTULO 3

Carolina Guimarães Castro, Karla Zancopé, Caio César Dias Resende, Flávio Domingues das Neves. Influence of the prosthetic index on fracture resistance of Morse taper dental implants. The International Journal of Oral & Maxillofacial Implants.

Influence of the prosthetic index on fracture resistance of Morse taper dental implants

Karla Zancopé, DDS, MS, PhD,[a] Caio César Dias Resende, DDS,[b] Carolina Guimarães Castro, DDS, MS[c] Rafael Calixto Salatti,[d] and Flávio Domingues das Neves, DDS, MS, PhD[e]

School of Dentistry, Federal University of Uberlândia

Presented at the 11th International Meeting of the Brazilian Osseointegration Academy, São Paulo, Brazil, October 2014.

[a] Post-doctoral research fellow, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG Brazil.

[b] Master student, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG Brazil.

[c] PhD student, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG Brazil.

[d] Graduate Student, Mechanical Engineering, Faculdades Objetivo, Curitiba, PR, Brazil.

[e] Professor, Department of Occlusion, Fixed Prostheses, and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, MG Brazil.

Corresponding author:

Prof. Dr. Flávio Domingues das Neves, Av. Pará, 1720, Bloco 4L, Anexo A, sala 4LA-42, Campus Umuarama, CEP: 38405-320, Uberlândia, Minas Gerais, Brazil Phone: +55-34-3218-2222 Fax: +55-34-3218-2626. E-mail: neves@triang.com.br

Abstract

Purpose: Recently, manufacturers have inserted a prosthetic index inside the Morse taper implants. However, it is still unclear if this mechanism could decrease the mechanical strength of Morse taper implants. The aim of this study was to evaluate the influence of the prosthetic index on fracture resistance of Morse taper dental implants.

Materials and methods: Thirty Morse taper implants were divided into 3 groups (n=10): implants without the prosthetic index and solid Morse taper universal post (Group NIS), implants with the prosthetic index and solid Morse taper universal post (Group WIS) and implants and abutments with prosthetic index (Group WIP). Fracture resistance (N) was determined by force application of a perpendicular load to the abutments with a universal testing machine. The statistical analysis was performed using the 1-way ANOVA, and Tukey's test was applied (a=.05). All tested groups were modeled for finite element stress analysis (FEA), simulating the same conditions. The metallographic analysis was used to identify the fracture distribution and the microstructure of the titanium alloy.

Results: There was no statistically difference between the values of all tested groups. Mean fracture resistances were 353.7 N for group NIS; 397.3 N for group WIS and 372.0 N for group WIP. According to the FEA, the prosthetic index region was out of stress, and the macroscopic failure pattern was exactly as demonstrated by FEA.

Conclusions: The presence of the prosthetic index on Morse taper implants did not decreased its resistance to fracture for the tested implants.

Key words: biomechanics; dental implants; mechanical stress; prosthetic index.

INTRODUCTION

Morse taper implants were inserted on dentistry to increase the prosthetic stability at the implant/abutment interface (I/A) and to decrease the effects of initial bone loss.[1,2] To reduce the risk of screw loosening or the appearance of a gap in the I/A interface, the abutment should remain fixed to the implant.[3-6] This prosthetic connection type has an internal junction that presents friction and mechanical imbrications, which decrease I/A interface gap.[7-9] This characteristic associated with the preload abutment-implant interface and occlusive forces is essential for this system stability,[10,11] predicting the rehabilitation behavior.[12]

Initially, the Morse taper implant used an external assembler system to ensure the surgery placement. Nowadays, inside the Morse taper implant, there is a prosthetic index[13] with this purpose. This "internal torque" allows implants to be placed with greater security, less time consuming and with great versatility, regarding to prosthetic abutments.[13]

It is still unclear if this prosthetic index could decrease the mechanical strength of Morse taper implants due to reduction of titanium wall thickness. Thus, prosthetic index might create an area with stress accumulation that could compromise the longevity of the Morse taper implant.[13,14] This fragility can be mechanically tested.[15-19] The bending test is an important method of assessing the mechanical behavior of dental implants.[20] The Finite Element Analysis (FEA) has also been used to assess the mechanical characteristics of dental implants, demonstrating stress distribution into complex structures.

Therefore, the aim of the present study was evaluated the influence of the internal index in Morse taper implants. The null hypothesis was that the presence of the prosthetic index would influence the implants resistance to fracture.

MATERIALS AND METHODS

Thirty conical Morse taper implants (Neodent) were divided in 3 groups (n=10): NIS (no index for the implant and no index abutment); WIS (with an index for the implant and no index abutment) and WIP (with an index for the implant and abutment), described on Table 1.

Sample preparation

The implants were positioned into a metallic holder, to receive loads at an angle of 90 degrees relative to the long axis. The implant shoulder was also positioned 4mm above the metallic holder, to isolate the prosthetic index and simulate marginal bone crest resorption. A metallic instrument was used to confirm this distance. The implant was then fixed to the metallic base with a screw, and the abutment was installed over the implants, according to manufacturer's torque recommendation.

Bending Test

The implant and the metallic holder were fixed on the mechanical testing machine (EMIC; 2000DL) and a stainless steel spherical point (4 mm diameter) connected to a load cell of 500 KN capacity (KN500; EMIC) was used to load the samples (Fig. 1). The universal testing machine applied the bending load at a crosshead speed of 0.5 mm/min. A computer mounted through association in the machine was programmed to interrupt the test cycle process for an upper 5.0 mm displacement or an abrupt strength decrease of the tested material. The load was applied at 2 mm of the abutment platform.

After each mechanical testing, the alignment of the stainless steel spherical point was conferred. The computer coupled to the load cell was programmed to record the

force (N) during flexion of the implant/ abutment versus displacement (mm) into graphics.

Finite Element Analysis

An implant-abutment complex was modeled, and the implant, abutment, and abutment screw design were supplied by the manufacturer (Neodent) in a *.IGES format. The stress analysis was performed using FEMAP with NX Nastran (v11.1.1 64-bits; Siemens).

All models were considered homogeneous, isotropic, and linearly elastic and the materials properties are described on Table 2. To create the mesh, semiautomatic meshing tool was used, with tetrahedral solid elements with quadratic trial function (element type SOLID187). The mesh consisted of a total of 228075 nodes and 148043 elements for group NIS; 124374 nodes and 80162 elements for group WIS; and 72737 nodes and 45456 elements for group WIP. The boundary conditions were determined with sliding contact with friction (0.2) between the abutment and implant.[21] The bottom nodes of the implant were held fixed to avoid movement of the model.

The load was applied exactly as described on the Bending test section, to simulate the same conditions and analysis the stress distribution into the implant, at the index region. Data were recorded using Von Mises criteria.

Metallographic analysis

The metallographic analysis was performed to identify the distribution of the different fracture modes obtained for the three different groups during the fatigue test, and the microstructure of the titanium ASTM F67-06 Grade IV alloy.

For this analysis, the fracture surfaces of samples were examined using an optical microscope (AxioVision Imager.A1m; Zeiss, Germany), with magnification ×50 and ×200. Prior to the analysis, the samples were submitted to acid treatment, in order to increase the visualization of the metallic characteristics.

Statistical Analysis

The statistical analysis of the force at fracture data was performed using the 1-way ANOVA, followed by the Tukey honestly significant difference test (a=.05). All analyses were performed with a statistical software (Sigma Plot version 12.0; Systat Software Inc.).

RESULTS

The mean and standard deviation of fracture data (N) are shown in Table 3. No significant difference (df=2, F=3.184, P=.058) was found among all groups. The presence of the prosthetic index did not decrease it resistance to fracture. The minimum and maximum displacements of all tested groups were presented on Table 4.

The stress distributions revealed that the prosthetic index region was free of stress. The stress accumulation occurred near the application of the load (Fig. 2a to 2c), according to FEA results.

The metallographic analysis revealed that the prosthetic index region was not affected by the reduction of titanium wall thickness (Fig. 3a to 3c). This analysis also revealed that a microstructure difference was observed, due to the improvement of the titanium alloy of the groups WIS and WIP (Fig. 4a to 4c).

DISCUSSION

The null hypothesis of this study was rejected. The presence of the prosthetic index did not decrease the tested implants resistance to fracture. The results of the present study was not expected, so a FEA was performed to understand the stress pattern into the Morse taper implants with the prosthetic index. The analysis demonstrated that the prosthetic index is not a stress concentration region. Also, the location of the fractures, demonstrated by metallographic analysis occurred at the same location, just as demonstrated by FEA.

Morse taper implants presents large contact surface with the abutments, forming a frictional locking.[3,7,22-24] Even though occlusal movements generate bending moments and upward tensile loads that may interfere negatively with the retention of the abutment, the axial compressive component of occlusal forces acts in the direction of abutment insertion, which increases contact pressure and frictional resistance.[11,14,25]

Manufactures added an internal prosthetic index on Morse taper implants and the positive index on abutments to improve implant installation and facilitate the position in the prosthetic steps.[13] However, abutments without index could be assembled to the implants with index. In these conditions, a higher empty space between implant and abutment, decreasing the contact surface could reduce the resistance and cause failures of I/A interface, justifying the concern about the data from the WIS group. However, the FEA demonstrated that the index region of the implants did not present stress concentration.

The metallographic analysis demonstrated that there were differences in the microstructure due to the improvement of the titanium alloy. According to the results of the present study, the groups WIS and WIP presented a more concise alloy (Fig. 4a to 4c). This improvement could improve the mechanical behavior of the implants with prosthetic index, regardless of the reduction of titanium wall thickness. Probably, the

differences in the microstructure between the groups could explain the lower mean of group NIS, however did not significant difference was found among all groups. It is important to understand that the values obtained by the bending test are clinically secure.

Different test methods have been used for evaluating the mechanical strength of implant/abutment connections.[15,17,19] In this study, the bending test was used. Severe bone reabsorption was simulated by positioning the implant 4 mm above the metallic holder. This step either isolates the prosthetic index. The samples were loaded by stainless steel spherical until failure or present 5 mm of displacement. All samples presented failure prior to reaching maximum displacement. The minimum and maximum displacement founded was 0.75 mm and 4.38 mm, respectively. Implant diameters in this study were 3.5 mm and implant lengths were 13 mm. These dimensions were chosen specially for comparing different implant designs with comparable dimensions.

CONCLUSION

Within the limitations of this in vitro study, all groups presented a standardization of resistance to fracture. The presence of the prosthetic index did not reduce the resistance to fracture of these Morse taper implants, but the manufacturer changed the titanium alloy to improve the biomechanics of the implant with prosthetic index.

ACKNOWLEDGEMENTS

The authors thank FAPEMIG, CNPq, CAPES, Neodent (Curitiba, Brazil) and NEPRO Research Group for the support. The authors also acknowledge CPBio - Biomechanics, Biomaterials and Cell Biology Dental Research Center.

REFERENCES

1- Mangano C, Mangano F, Piattelli A, Iezzi G, Mangano A, La Colla L. Prospective clinical evaluation of 1920 Morse taper connection implants: results after 4 years of functional loading. Clin Oral Implants Res 2009;20:254-261.

2- Papaspyridakos P, Chen CJ, Chuang SK, Weber HP, Gallucci GO. A systematic review of biologic and technical complications with fixed implant rehabilitations for edentulous patients. Int J Oral Maxillofac Implants 2012;27:102-110.

3- Broggini N, McManus LM, Hermann JS, Medina RU, Oates TW, Schenk RK, et al. Persistent acute inflammation at the implant–abutment interface. J Dent Res 2003;82:232-237.

4- Broggini N, McManus LM, Hermann JS, Medina R, Schenk RK, Buser D, et al. Periimplant inflammation defined by the implant-abutment interface. J Dent Res 2006;85:473-478.

5- Rodrigues Neto DJ, Cerutti-Kopplin D, do Valle AL, Pereira JR. A method of assessing the effectiveness of the friction fit interface by measuring reverse torque. J Prosthet Dent 2014;112:839-842.

6- Cerutti-Kopplin D, Rodrigues Neto DJ, Lins do Valle A, Pereira JR. Influence of reverse torque values in abutments with or without internal hexagon indexes. J Prosthet Dent 2014;112:824-827.

7- Dibart S, Warbington M, Su MF, Skobe Z. In vitro evaluation of the implant-abutment bacterial seal: the locking taper system. Int J Oral Maxillofac Implants 2005;20:732-737.

8- Koutouzis T, Wallet S, Calderon N, Lundgren T. Bacterial colonization of the implant-abutment interface using an in vitro dynamic loading model. J Periodontol 2011;82:613-618.

9- Ricciardi Coppedê A, de Mattos M da G, Rodrigues RC, Ribeiro RF. Effect of repeated torque/mechanical loading cycles on two different abutment types in implants with internal tapered connections: an in vitro study. Clin Oral Implants Res 2009;20:624-632.

10- Merz BR, Hunenbart S, Belser UC. Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. Int J Oral Maxillofac Implants 2000;15:519-526.

11- Bozkaya D, Muftu S. Mechanics of the tapered interference fit in dental implants. J Biomech 2003;36:1649-1658.

12- Nentwig GH. Ankylos implant system: concept and clinical application. J Oral Implantol 2004;30:171-177.

13- Perriard J, Wiskott WA, Mellal A, Scherrer SS, Botsis J, Belser UC. Fatigue resistance of ITI implant-abutment connectors -- a comparison of the standard cone with a novel internally keyed design. Clin Oral Implants Res 2002;13:542-549.

14- Castro CG, Zancopé K, Veríssimo C, Soares CJ, Neves FD. Strain analysis of different diameter Morse taper implants under overloading compressive conditions. Braz Oral Res 2015;29:1. Epub 2015 Jan 23.

15- Sailer I, Sailer T, Stawarczyk B, Jung RE, Heammerle CH. In vitro study of the influence of the type of connection on the fracture load of zirconia abutments with

internal and external implant-abutment connections. Int J Oral Maxillofac Implants 2009;24:850-858.

16- Kim KS, Kim YL, Bae JM, Cho HW. Biomechanical comparison of axial and tilted implants for mandibular full-arch fixed prostheses. Int J Oral Maxillofac implants 2011;26:976-984.

17- Dittmer MP, Dittmer S, Borchers L, Kohorst P, Stiesch M. Influence of the interface design on the yield force of the implant-abutment complex before and after cyclic mechanical loading. J Prosthodont Res 2012;56:19-24.

18- Gehrke SA. Importance of Crown Height Ratios in Dental Implants on the Fracture Strength of Different Connection Designs: An In Vitro Study. Clin Implant Dent Relat Res 2013 Oct 24. Epub ahead of print.

19- Ugurel CS, Steiner M, Isik-Ozkol G, Kutay O, Kern M. Mechanical resistance of screwless morse taper and screw-retained implant-abutment connections. Clin Oral Implants Res 2015;26:137-142.

20- Schmitt CM, Nogueira-Filho G, Tenenbaum HC, Lai JY, Brito C, Döring H, et al. Performance of conical abutment (Morse Taper) connection implants: a systematic review. J Biomed Mater Res A 2014;102:552-574.

21- Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10:529-536.

22- Aloise JP, Curcio R, Laporta MZ, Rossi L, da Silva AM, Rapoport A. Microbial leakage through the implant-abutment interface of Morse taper implants in vitro. Clin Oral Implants Res 2010;21:328-335.

23- Teixeira W, Ribeiro RF, Sato S, Pedrazzi V. Microleakage into and from two-stage implants: An in vitro comparative study. Int J Oral Maxillofac Implants 2011;26:56-62.

24- King GN, Hermann JS, Schoolfield JD, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in submerged dental implants: a radiographic study in the canine mandible. J Periodontol 2002;73:1111-1117.

25- Bressan E, Lops D, Tomasi C, Ricci S, Stocchero M, Carniel EL. Experimental and computational investigation of Morse taper conometric system reliability for the definition of fixed connections between dental implants and prostheses. Proc Inst Mech Eng H 2014;228:674-681.

FIGURE LEGENDS

Fig. 1: Metallic holder and the stainless steel spherical point loading the sample, performing the bending test.
Fig. 2: FEA image: a- NIS group, b- WIS group, c- WIP group.
Fig. 3: Metallographic analysis: a- NIS group, b- WIS group, c- WIP group. Magnification ×200.
Fig. 4: Microstructure of the titanium alloy: a- NIS group, b- WIS group, c- WIP group. Magnification ×200.

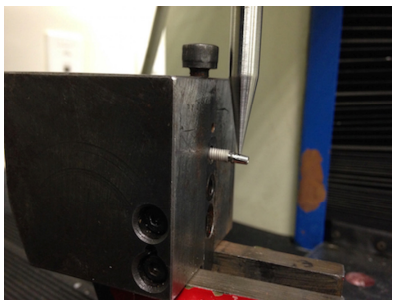

Figure 7

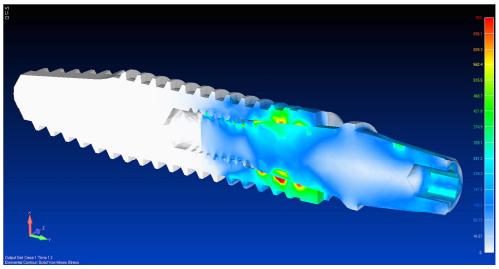

Figure 8A

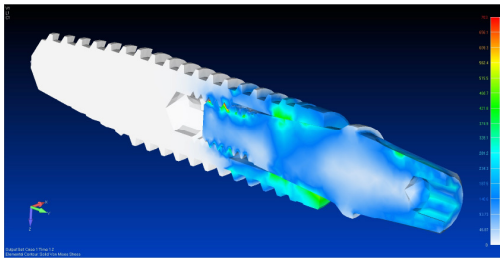

Figure 2B

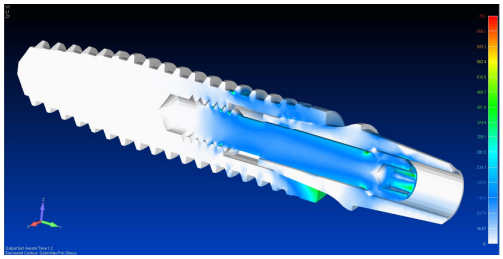

Figure 2C

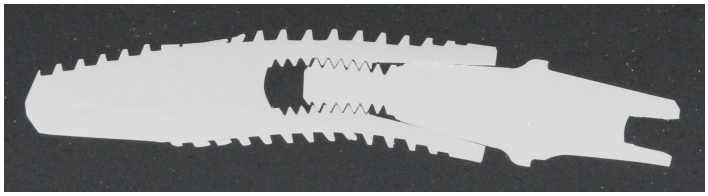

Figure 9A

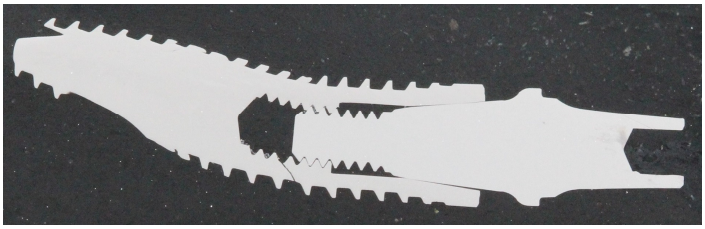

Figure 3B

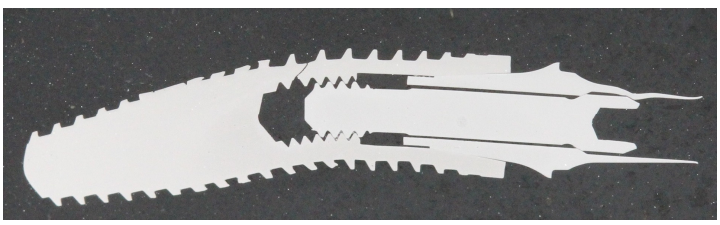

Figure 3C

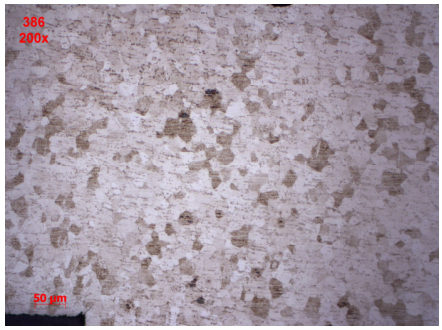

Figure 10A

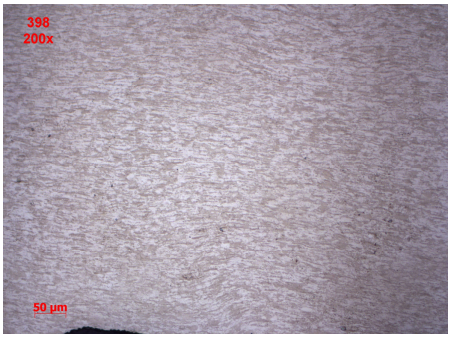

Figure 4B

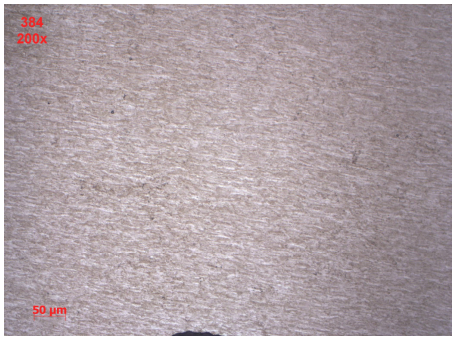

Figure 4C

TABLES

Table 1. Groups descriptions.

Groups	Description
NIS	Alvim CM (without prosthetic index, ø 3.5 x 13.0mm) and solid CM Universal Post (ø 3.3 x 4.0 x 1.5mm).
WIS	Alvim CM (3.5mm x 13.0mm) and solid CM Universal Post (ø 3.3 x 4.0 x 1.5mm).
WIP	Alvim CM (3.5mm x 13.0mm, Neodent, Curitiba, Brazil) and CM exact universal post (ø 3.3 x 4.0 x 1.5mm) with passing bolt.

NIS (no index for the implant and no index abutment); WIS (with an index for the implant and no index abutment); WIP (with an index for the implant and abutment).

Table 2. Material properties.

Structure	Young's Modulus (Mpa)	Poisson's Ratio (V)	Yeld stress ratio (Mpa)
Titanium Grade IV	103000	0.361	703
Ti6Al-4V-ELI Titanium alloy	105000	0.361	881

Table 3. Mean fracture results and standard deviation.

Groups	NIS	WIS	WIP
Mean values	353.7±51.9 N^A	397.3±12.5 N^A	372.0±40.8 N^A

NIS (no index for the implant and no index abutment); WIS (with an index for the implant and no index abutment); WIP (with an index for the implant and abutment). Means followed by different letters indicate statistically significant difference at 5% when horizontally compared.

Table 4. Displacement results (mm).

	NIS		WIS		WIP	
	Min	Max	Min	Max	Min	Max
Displacement	0.75	3.78	2.44	3.44	0,98	4,38

NIS (no index for the implant and no index abutment); WIS (with an index for the implant and no index abutment); WIP (with an index for the implant and abutment); Min: minimum displacement; Max: maximum displacement.

CAPÍTULO 4

Carolina Guimarães Castro, Carlos José Soares, Karla Zancopé, Alexsander Luiz Golin, Rafael Calixto Salatti, Flávio Domingues das Neves. Comparison of different methods to simulate the pre-load condition in Morse taper implant applied on Finite Element Analysis. Journal of Prosthetic Dentistry.

Abstract

Statement of problem There is no consensus in literature about simulation for Morse taper dental implants on finite element analysis.

Purpose The aim of this study was to enhance the understanding of the mechanics of the Morse taper implant, including to test different methods for simulating of pre-load between the abutment and the implant conical interface.

Material and Methods Two 3D non-linear finite element models were created, the materials were considered isotropic, linear and elastic. The mechanical properties were extracted from raw material certificate and literature. The contact areas were defined as non-linear, with 0.2 friction coefficient. The von Mises stress criteria was used as the evaluation the stress distribution.

Conclusion Within the limitations of this study, it was demonstrated that a great percentage of tightening torque applied over the abutment is required to overcome friction in the abutment/implant conical connection, leaving only a limited stress concentrated at thread area. Furthermore, this study showed that the both presented methods resulted in similar stress distribution pattern along the implant/abutment interface.

Clinical Relevance

A complete understanding of the mechanical principle of Morse taper implants can help clinicians to anticipate some biological events. The great friction between implant/abutment is one the responsible to guarantee minimum micromovements and a stable connection to adjacent tissue.

Key-words

Morse taper implants; finite element analysis; pre-load.

Introduction

The mechanical stability between implant and abutment is an important issue in modern implantodology[1]. The maintenance of the screw tightening is totally dependent on mechanical principle of the implant connection[2,3]. Changes in the factors considered influential to the preload, such as the antirotational properties of the abutment, the settling effect, and functional loads, may play a fundamental role in screw loosening[4]. The absence of mechanical stability in the interface implante/abutment results consequently in biological problems due micromovements that can stimulate crestal bone resorption[5].

Many years ago, the principle of Morse taper implant-abutment connection was introduced in oral implantology[1]. The main difference compared with other systems is certainly the tapered connection, which provides excellent biological and mechanical stability with unusual prosthetic versatility[6]. Morse taper implant-abutment connection is based on the principle of ‘‘cold welding’’ obtained by high contact pressure and frictional resistance between the surfaces of the implant and the abutment[7,8]. In the case of taper Morse junction, the biting force acts in the direction of the abutment insertion, hence aids to secure the connection. This situation is in contrast to implants using screws where the biting force lowers the pretension in the screw[9,10].

If a symmetrical bolted connection is tightened by turning the nut a tensile load, nominated as preload, is placed on the bolt and an equal compressive load between the plates. In this way the bolt is elongated and the plates are compressed[11]. When the ratchet is used to tighten the abutment, the tightening torque required to overcome the force moment (M) generated by thread friction. The friction in the joint could be calculated by the equation cited

by Merz et al.[12]. Have been demonstrated the behaviors of Morse taper and Butt Joint connections, by finite element analysis considering the different mechanical principles between these two implant systems[12,13]. There is no consensus in literature about the simulation of Morse taper dental implants on finite element analysis. Several studies[14-17] have been ignored a differential characteristic of Morse taper junction, during contours definitions in FEA simulations: tapered connection (implant/abutment) with high contact pressure and frictional resistance.

Considering the definition that all tightening torque result in a pre-load condition between the parts, the aim of this study was to compare two different ways to simulate the pre-load condition in Morse taper implant. The null hypothesis was that there is no difference in stress distribution along the implant/abutment junction regarding the simulation method used.

Material and Methods

Two 3D models with Morse taper implant were simulated and analyzed by finite element method, varying the method of pre-load simulation: 1) by resultant pre-load value or 2) by insertion torque value. Both 3D models were imported as .STL file, from Inventor software (Autodesk, Inc, San Rafael, CA). The spiral characteristic of the threads in the abutment was maintained in the present study. Non oblique load was applied in models.

For the first model, the pre-load simulation between the implant and abutment was initially based on following equation[12]:

$$M_{\text{tightening}} = M_{\text{thread friction}} + M_{\text{joint friction}} \quad \text{(E1)}$$

Based on concepts of forces and deformations in joints due to preload[11], the axial preload (F_v) from tightening moment, can be determined by:

$$M\,\text{tightening} = Fv \times (0.159 \times P + \mu \times 0.577 \times D2) + Fv \times Dc + \mu \times 1/\cos\alpha \quad (E1)$$

where P= screw pitch, D_2= mid-diameter of the flank of screw thread, D_c= mid-diameter of the cone, α= angle between implant axis and surface orthogonal in the cone, and μ= coefficient of friction. This formula was developed for triangular thread where α=60°[11].

The formula presented was only described for one-piece abutment[12]. When two-pieces abutment was considered in this study, the formula suffered some modifications, because there are 2 conical interfaces present in the system. The first one is between the abutment and implant, and the second is between the screw and abutment. So, for two-pieces abutment simulation, the basic formula must to be:

$$M\,\text{tightening} = M\,\text{thread friction} + M\,\text{joint friction abutment/implant} + M\,\text{joint friction screw/abutment} \quad (E2)$$

Based on the same mechanical concepts, the formula can be determined by:

$$M\,\text{tightening} = F_v \times (0.159 \times P + \mu \times 0.577 \times D_2) + F_v \times D_{c1} + \mu_1 \times 1/\cos\alpha + F_v \times D_{c2} + \mu_2 \times 1/\cos\beta \quad (E2)$$

where P= screw pitch, D_2= mid-diameter of the flank of screw thread, D_{c1}= mid-diameter of the abutment cone, α = angle between implant axis and surface orthogonal in the cone, μ_1= coefficient of friction between implant and abutment, D_{c2}= mid-diameter of the screw cone, β= angle between screw axis and surface orthogonal in the abutment and μ_2= coefficient of friction between screw and abutment. Based on these formulas, the obtained preload values

were 150N for 2 pieces abutment (Neodent, PR, Brazil). Indeed, these values were used at respective formulas to calculate the distribution of total pre-load between the different regions: thread friction, joint friction abutment/implant and joint friction screw/abutment.

Different ways to introduce the axial preload into the model has been described, firstly is calculated how much of tightening torque is required to overcome friction in the conical connection and how much is absorbed by the threads and, with the help of a layer of temperature sensitive elements, the value was introduced[12]. In the present study the sequence was to calculate tightening torque distributed in the conical connection and in the threads[12]. The screw was cut in 2 parts, in the middle of the two support regions of the screw. The calculated preload value for the thread friction added to calculated preload for the joint friction screw/abutment were incorporated into the "bolt preload element" as axial preload using Femap/Nx Nastran softwares (Siemens, EUA) (Figure 1). This calculation indicated that 84% of the tightening torque is concentrated in joint friction abutment/implant.

For the second model, the 3D finite element analysis was conducted using Adina software (Adina System, Germany). The difference between this model and the first one, was the method used to simulate the screw tightening torque. This condition was applied just as insertion torque at the screw head, as occurs clinically (Figure 2). For this condition, was not necessary to cut the screw model in 2 parts. The original .STL models were just assembled between to be imported in the Adina software.

For both models, the meshed was generated using 10-node tetrahedral elements (TET10). A finer mesh, which converge for stable and consistent

results (Figure 3), was generated at the implant-abutment interface to ensure accuracy in stress calculation[13]. The materials were considered isotropic, linear and elastic and their mechanical properties extracted by literature were inputted in the models (Table 1). The contact areas were defined as non-linear, with 0.2 friction coefficient[9,18]. The constraints definitions were established as fixed in the x, y, and z axes at the mesial and distal boundary surfaces of the cylinder like occurs in the mechanical experiments in testing machine.

Results

For both models, it was observed a great percentage of stress distribution in the abutment/implant conical connection, leaving only a limited stress concentrated at thread area (Figure 4). The stress distribution in the screw abutment was different according the method of simulating preload (Figure 4).

There was not influence of simulating method in stress distribution along the implant/abutment junction (Figures 4 and 5).

Discussion

The understanding of mechanics of Morse taper implants is essential to differentiate the FEA simulation of preload conditions between different implant junctions, i.e., between Morse taper and butt joint connections[12]. A complicating factor in finite element analysis is the specification of the conditions of the connectivity between the components of the complex structure[13]. Contact and friction play crucial roles in the mechanical behavior of two parts of a complex,

including oral implants[2,4,12]. In the case of Morse taper connection, the friction at tapered connection results in high contact pressure and frictional resistance, leaving only a limited strain that must be absorbed by the abutment screw thread, different to butt joint where the screw alone maintains the abutment connected to implant[12]. If the taper connection is treated only with friction contact, the system will be considered similar to an external hexagon joint. In this condition, there is no form lock or positive locking and the axial preload of the abutment screw is the only determining factor for stability of the connection[12].

In a taper connection, form lock and friction are the basic principles[12] while in external hexagon, pure clamping is the underlying principle[9]. The FEA result of the first model indicated the tightening torque value concentrated in joint friction of 84% of total pre-load value. The difference between the two models presented in this study is the simulation of or the recommended torque is 15Ncm (second model) or of the resultant pre-load of the recommend torque (150N), obtained by the presented formula.

It was demonstrated in the present study that great tightening torque intensity applied over the abutment is required to overcome friction in the abutment/implant conical connection, leaving limited stress concentration at thread's area. Considering the Saint-Venant´s Principle that assumed the point sufficiently far enough from the point of loaf application that the distribution of normal stress is uniform, is not recommended the evaluation of stress distribution in the thread screw area in the first model simulated in the present study. This occurrence is justified by the load application in the beam created between the two cut parts of the screw. So, by this point of view, the simulation

using software, which support the application of tightening torque at the screw head, allows the analysis of resultant stress in the thread screw as well, and not in the implant/abutment interface. Another important issue to point for the resultant pre-load method (first model) is that the geometric characteristics must be considered and differentiated for each new simulation, depending on the particularities of thread and implant designs, of abutment model and of recommended insertion torque of abutment, according to the variables of the formula described.

Conclusion

No difference in the stress distribution along the implant/abutment junction was found for both methods to simulate the pre-load condition in Morse taper implants. However, the possibility to choice a software that allows the application of torque value directly at the screw head tend to be more predicable for the analysis of the screw thread region.

References

1. Mangano C, Mangano F, Shibli JA, Tettamanti L, Figliuzzi M, d'Avila S, Sammons RL, Piattelli A. Prospective evaluation of 2,549 Morse taper connection implants: 1- to 6-year data. J Periodontol. 2011 Jan;82(1):52-61.
2. Sakaguchi RL, Borgersen SE. Nonlinear contact analysis of preload in dental implant screws. Int J Oral Maxillofac Implants. 1995 May-Jun;10(3):295-302.
3. King GN, Hermann JS, Schoolfield JD, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in non-submerged

dental implants: a radiographic study in the canine mandible. Journal of Periodontology. 2002;73: 1111-1117.

4. Bulaqi HA, Mousavi Mashhadi M, Safari H, Samandari MM, Geramipanah F. The dynamic nature of abutment screw retightening: Finite element study of the effect of retightening on the settling effect. J Prosthet Dent. 2015 Mar 4. [Epub ahead of print]
5. Nentwig GH. Ankylos implant system: concept and clinical application. J Oral Implantol. 2004;30(3):171-7.
6. King GN, Hermann JS, Schoolfield JD, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: A radiographic study in the canine mandible. J Periodontol 2002;73:1111-1117.
7. Albrektsson T. A multicenter report on osseointegrated oral implants. J Prosthet Dent. 1988 Jul;60(1):75-84.
8. Cochran D. Review: Implant I. In: Annals of Periodontology. Vol 1: 1996 World Workshop in Periodontics. Chicago: American Academy of Periodontology, 1996.
9. Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants. 1995 Sep-Oct;10(5):529-36.
10. Bozkaya D, Müftü S. Mechanics of the tapered interference fit in dental implants. J Biomech. 2003 Nov;36(11):1649-58.
11. Beitz W. Küttner KH (eds.) Dubbel's Handbook of mechanical engineering. Dubbel H. [Taschenbuch für den Maschinenbau. English]; ed 18. Berlin: Springer-Verlag, 1994. p.F38.

12. Merz BR, Hunenbart S, Belser UC. Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. Int J Oral Maxillofac Implants. 2000 Jul-Aug;15(4):519-26.
13. Sannino G, Barlattani A. Mechanical evaluation of an implant-abutment self-locking taper connection: finite element analysis and experimental tests. Int J Oral Maxillofac Implants. 2013 Jan-Feb;28(1):e17-26.
14. Pessoa RS, Muraru L, Júnior EM, Vaz LG, Sloten JV, Duyck J, Jaecques SV. Influence of implant connection type on the biomechanical environment of immediately placed implants - CT-based nonlinear, three-dimensional finite element analysis. Clin Implant Dent Relat Res. 2010 Sep;12(3):219-34.
15. Pessoa RS, Coelho PG, Muraru L, Marcantonio E Jr, Vaz LG, Vander Sloten J, Jaecques SV. Influence of implant design on the biomechanical environment of immediately placed implants: computed tomography-based nonlinear three-dimensional finite element analysis. Int J Oral Maxillofac Implants. 2011 Nov-Dec;26(6):1279-87.
16. Yamanishi Y, Yamaguchi S, Imazato S, Nakano T, Yatani H. Influences of implant neck design and implant-abutment joint type on peri-implant bone stress and abutment micromovement: three-dimensional finite element analysis. Dent Mater. 2012 Nov;28(11):1126-33.
17. Toniollo MB, Macedo AP, Rodrigues RC, Ribeiro RF, Mattos MD. A three-dimensional finite element analysis of the stress distribution on morse taper implants surface. J Prosthodont Res. 2013 Jul;57(3):206-12.
18. Lang LA, Kang B, Wang RF, Lang BR. Finite element analysis to determine implant preload. J Prosthet Dent. 2003 Dec;90(6):539-46.

Tables

Table 1. Mechanical properties of the materials.

Structure	Raw Material	Young´s Modulus (GPa)	Poisson's ration	Reference
Morse taper Implant	Titaniun Grade 4	103	0.36	Raw Material Certificate, USA; according to "ASTM F 67"
Abutment	TI6AL4V-ELI	105	0.36	Raw Material Certificate, USA; according to "ASTM F 136"

Legends

Figure 1 – A) Screw abutment cut in 2 parts; B) Simulation of “bolt preload element” between the 2 parts of the screw , C) “Bolt preload element” in detail.

Figure 2 – Detail of application torque area at the screw head.

Figure 3 – A) Meshed implant; B) Meshed abutment in detail , C) Meshed screw in detail.

Figure 4 – von Mises stress ditsribution into the implant/abutment: A) with “Bolt preload element”; B) with tightening torque application.

Figure 5 – von Mises analysis in the implant: A) with “Bolt preload element”; B) with tightening torque application.

Figures

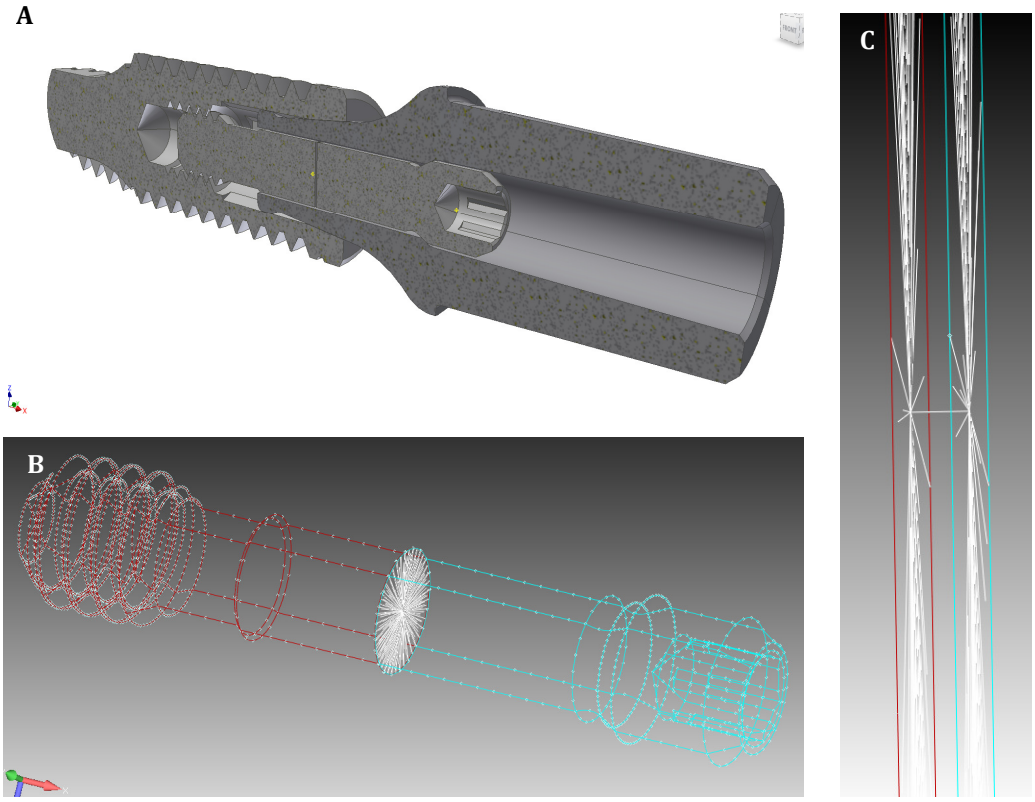

Figure 1

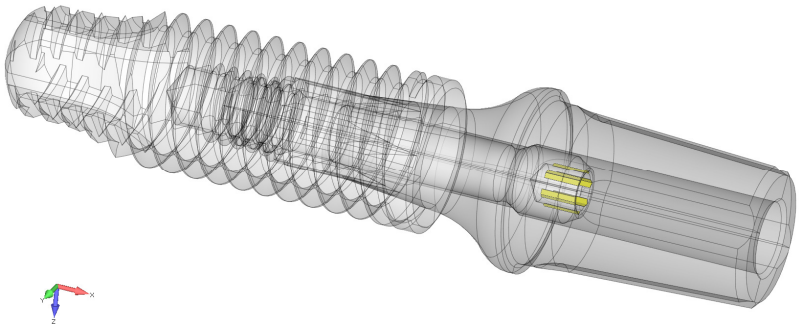

Figure 2

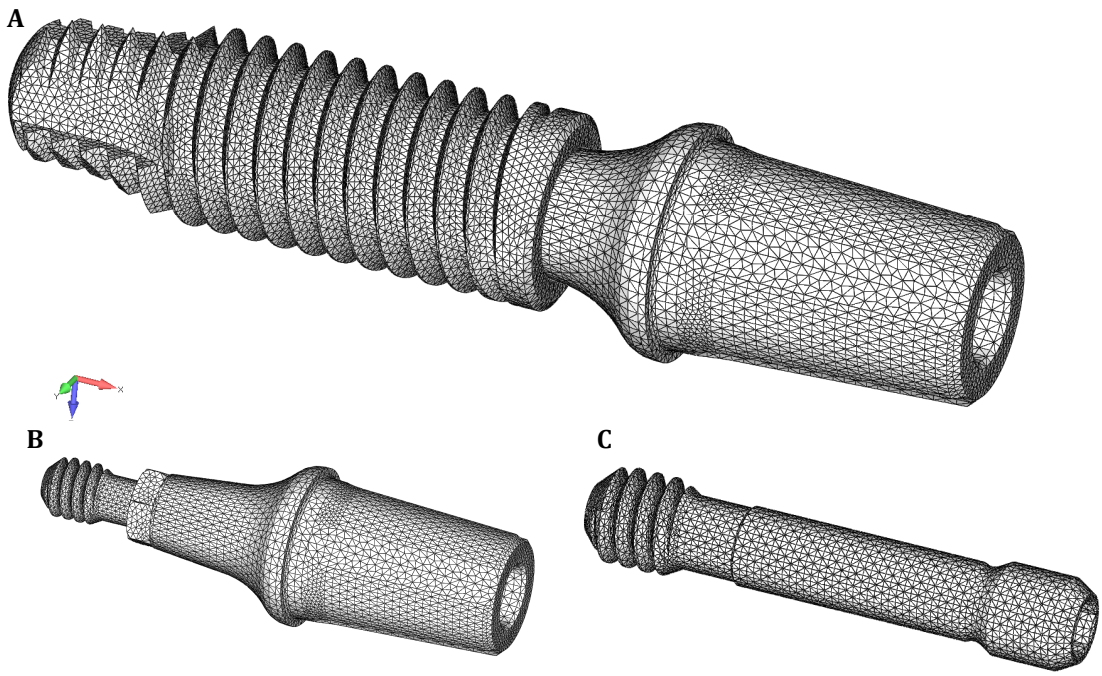

Figure 3

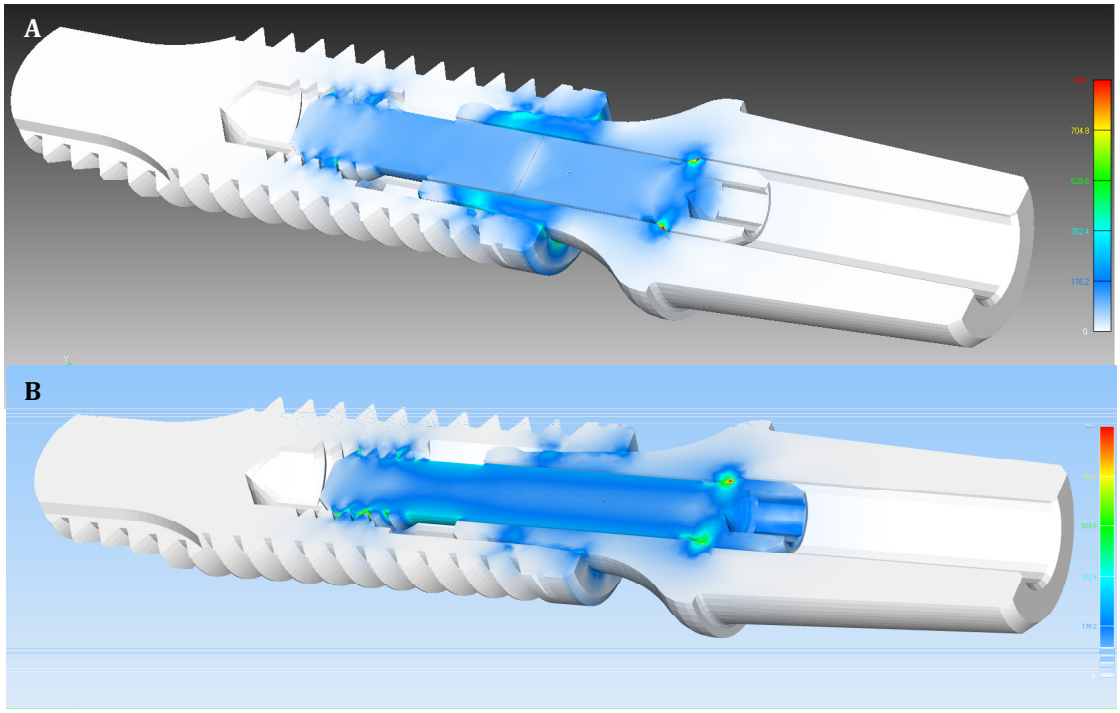

Figure 4

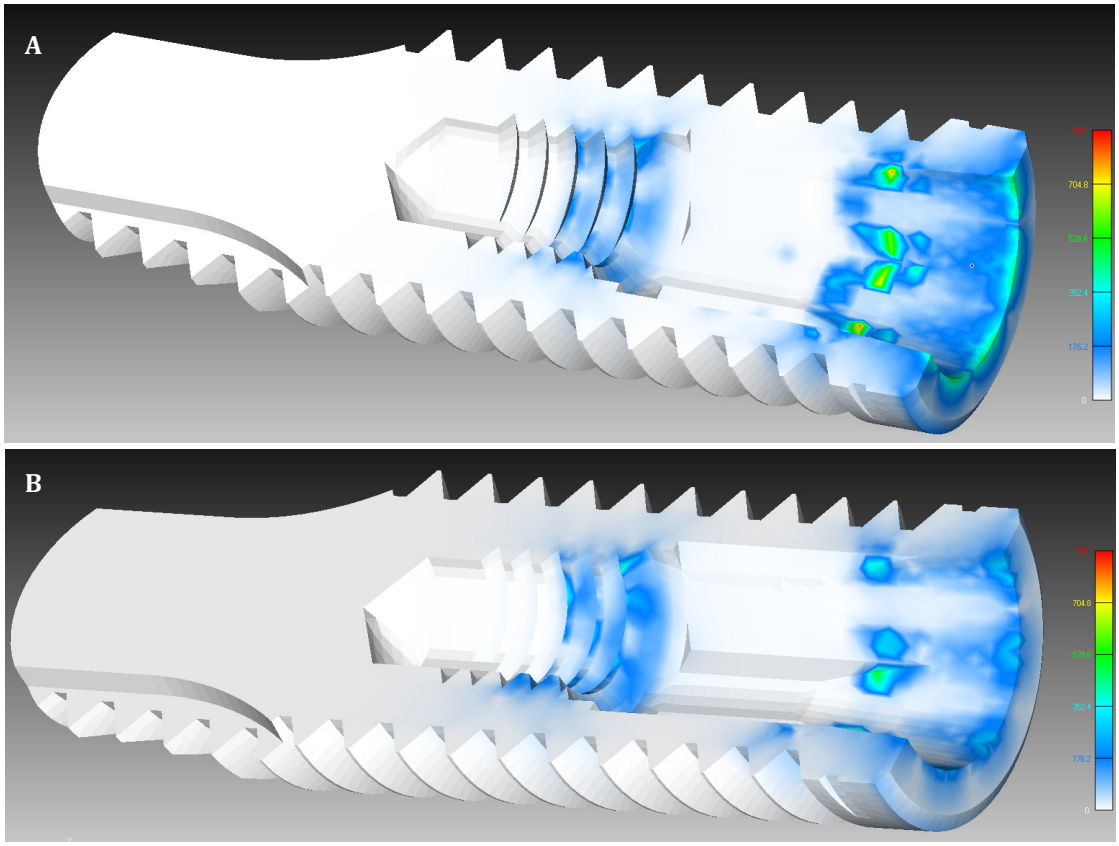

Figure 5

CAPÍTULO 5

Carolina Guimarães Castro, Karla Zancopé, Rafael Calixto Salatti, Robson Botolo da Silva, Elington Rodrigues, Flávio Domingues das Neves. Integrity of Morse taper Implants after fatigue vertical and off-center load. Clinical Oral Implants Research.

Abstract

Objective: The aim of the present study was to evaluate the integrity of Morse taper implant assembled with 2 pieces abutment after fatigue test, regarding deformation and microleakage.

Material and methods: 19 Morse taper implants were specific manufactured with an internal channel for the present study. The implants were divided in 5 groups according the methodology of evaluation and the step of fatigue test: 3D measurements, optical microscopy and microleakage. Three groups were submitted to 1 million dynamic cycles under 116N vertical and off-center load.

Results: All samples submitted to dynamic fatigue achieved the end of the 1 million cycles with no failure. The 3D measurements of group A samples showed no change in the evaluated dimensions, for both analysis: assembled and disassembled. For microleakage test, in the 80 minutes reading leak was observed in 1 sample from group B (with fatigue) and in 3 samples of group D. The microscopy analysis demonstrated no deformation in the tapered portion of the implants, confirming the 3D measurements results and the absence of failure after fatigue tests.

Conclusion: In the present study, 1 million fatigue cycles with load applied in vertical direction off-center of implant had no negative influence in the integrity of Morse taper implant with 2 pieces abutment assembly.

Introduction

One hundred and fifty years ago, in 1864, the Morse Taper concept was defined by Stephen A. Morse, an enterprising mechanic, who developed it to reliably join two rotating machine components (Hernigou et al., 2013). More than 25 years ago, the Morse taper principle was applied in oral implantology (Moser, Nentwig, 1989). When compared to hexagonal prosthetic interfaces, the tapered junction of Morse taper results in an excellent mechanical stability large contact pressure and resulting frictional resistance between the implant and the abutment (Albrektsson, 1988; Cochran, 1996; Bozkaya & Müftü, 2003).

As the hexagonal configurations depend totally on the screw abutment pre-load to maintain the stability between implant and abutment (Burguete et al., 1994; Sakaguchi & Borgersen, 1995; Bozkaya & Müftü, 2003; Haack et al.,

1995; McGlumphy et al., 1998), the masticatory axial loading could results in the abutment screw loosening (Schwarz, 2000). To tapered interface, form lock and friction are the basic principles to a secure and effective connection (Merz et al., 2000; Bozkaya & Müftü, 2003).

Morse taper system avoids micromoviments in the implant/abutment (I/A) interface contributing to a minimum inflammation level in the adjacent tissue (Dibart et al., 2005) and to a less crestal-bone loss adjacent to implant (King et al., 2002; Hansson 2003). To optimize the prosthetic indexation, such a keying device, an implant company added an internal geometric index mid-level of the cone of the implant body (Perriard et al., 2002). After a comparison regarding the mechanical strength between the Morse taper systems, with and without the internal index, Perriard et al. (2002) observed no difference between the standard cone and the newly designed internally keyed design. Still under mechanical scenario, a clinical study evaluating 2549 Morse taper implants after 6 years under loading concluded that the high mechanical stability of tapered connection is the responsible for the significant reduction of prosthetic failures or complications (Mangano et al., 2011).

Although the high survival rate of Morse taper implants, a lot of questions still motivate scientific researches. Among them, could be cited if is there abutment displacement into the implant over time and could this displacement put in risk the stability of tapered connection? The understanding of basic mechanical principles allows guide the understanding of mechanical behavior of dental implants submitted to different load conditions. The association of methodologies provides different points of view of the same mechanical occurrence.

The aim of the present study was to evaluate the integrity of Morse taper implant assembled with 2 pieces abutment after fatigue test, regarding deformation and microleakage. The null hypothesis is that 1 million fatigue cycles with load applied in vertical direction off-center of implant has no influence in the implant/abutment integrity.

Material and Methods

Nineteen Morse taper implants (Titamax Morse taper Implant 4.0x13.0mm code: 109.620, Neodent, Brazil) were specific prepared for the

present study. The samples were manufactured with a channel from the apical to the base of the screw chamber within the implant (Figure 1). The samples were divided in 5 groups, according the methodologies that them were submitted (Figure 2).

Figure 1 – Implant with hole assembled to abutment.

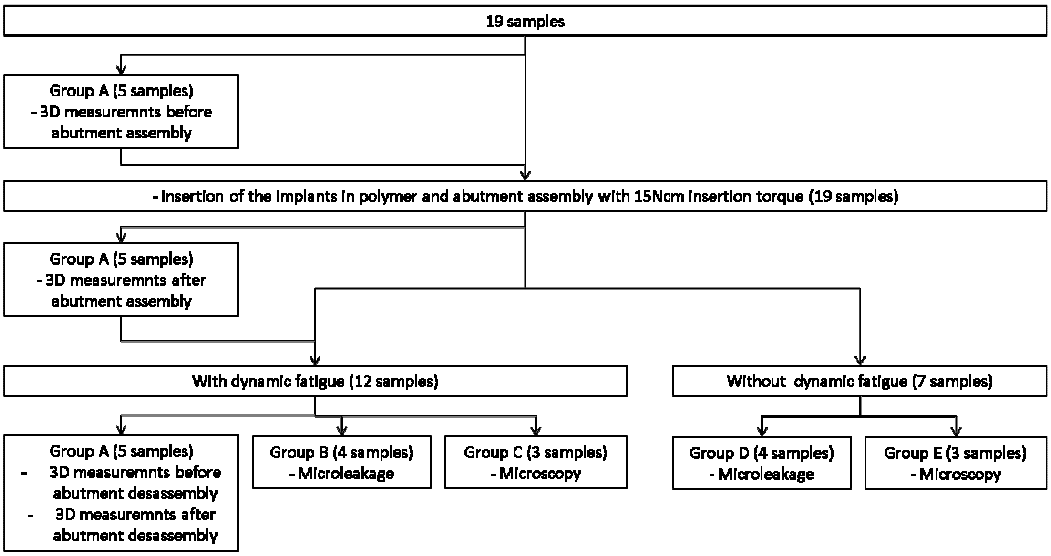

Figure 2 – Division of the groups, according to different methodologies.

As described in Figure 2, 5 (group A) of the 19 implants were submitted to tridimensional measurements (Optiv 222, Hexagon, Germany) regarding the external and internal diameters of implant and the internal taper angle. After these first measurements, all implants were inserted in polymer with a hole, maintaining 3mm of cervical region of implant exposed, according to ISO 14801. After, the implants were assembled to 2 pieces Morse taper abutments (Universal Abutment CM Exact, 4.5x4.0x2.5mm, Neodent) with 15Ncm insertion torque, as recommended by manufacturer (Figure 3).

Figure 3 – Abutment assembled to implant with 15Ncm insertion torque.

After assembly, the samples of group A were submitted to tridimensional measurements regarding the external implant diameter in the cervical portion and the height between the abutment and implant platform.

Twelve samples (including the 5 samples of group A) were submitted to dynamic fatigue according the set up published by Perriard et al., 2002. The samples were inclined by 15° off the vertical and a T-shaped bar was positioned over the abutment and the loading was applied in a vertical direction at 5mm off-implant center onto one end of the horizontal bar (Figure 4). The samples were submitted to 1 million cycles under a load of 116N and 15Hz frequency in Instron model E3000 machine (Instron, United Kingdon). During the test the minimum force was 10% of maximum load, 11.6N.

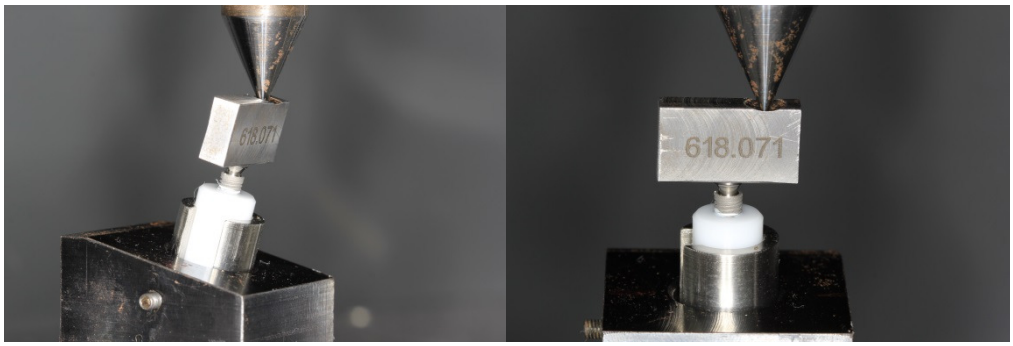

Figure 4 – Fatigue testing set up.

The 12 samples submitted to fatigue test were allocated in the groups A, B and C, according to Figure 2. The samples of group A (5 samples) were submitted to tridimensional measurements before and after disassembly

between abutment and implant. The samples of groups B and D (4 samples each group) were submitted to microleakage evaluation. The samples of groups C and E (3 samples each group) were analyzed by optical microscopy.

The microleakage test was performed based on methodology described by Gross et al., 1999. The interface between the cervical of implant and the polymer was sealed with silicon, and a polymer was assembled into the abutment, both to avoid the leakage for these ways. Each sample was positioned in a poliacetal tube assembled to a system designed to introduce controlled air pressure to 8 tubes. The samples were suspended in water and 0.3ml of gentian violet (Farmax, Brazil) was inserted into the polymer tube where the implant was assembled (Figure 5). After, a constant air pressure of 2 Bars was achieved and the readings were taken at intervals of 5, 20 and 80 minutes from the time of initial pressure activation.

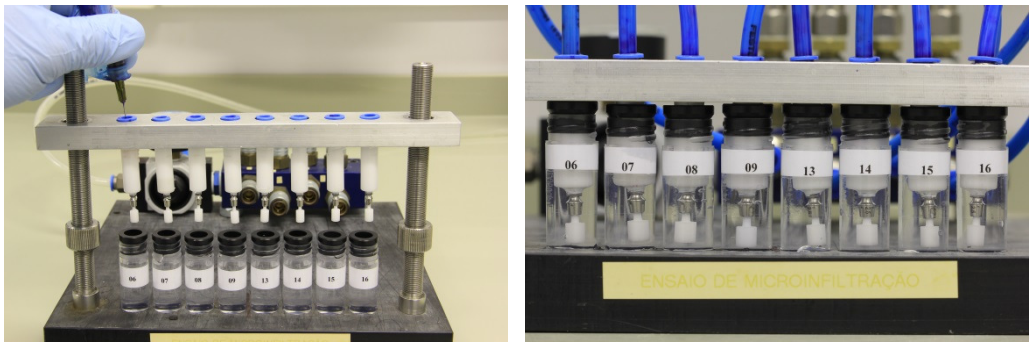

Figure 5 – Microleakage testing set up.

For microscopy analysis, the samples from groups C and E (3 samples for each group) were embedded in resin (CitoPress1, Struers, USA), sanded (TegraSystem, Struers) and evaluated in optic microscope (AxionVision Imager A1m, Zeiss, Germany).

Results

All samples submitted to dynamic fatigue achieved the end of the 1 million cycles with no failure.

The 3D measurements of group A samples showed no change in the evaluated dimensions, for both analysis: assembled and disassembled. The

media value for height between the abutment and implant platform was 6.32 mm before and after fatigue test.

For microleakage test, in the 5 minutes reading, gentian violet leak was observed in 2 samples from group D (without fatigue). In the 80 minutes reading leak was observed in 1 sample from group B (with fatigue) and in 3 samples of group D.

Figure 6 – 80 minutes reading during the microleakage test. It was observed gentian violet leak in the samples 09 (from group B), 13, 15 and 16 (from group D).

The microscopy analysis demonstrated no deformation in the tapered portion of the implants, confirming the 3D measurements results and the absence of failure after fatigue tests.

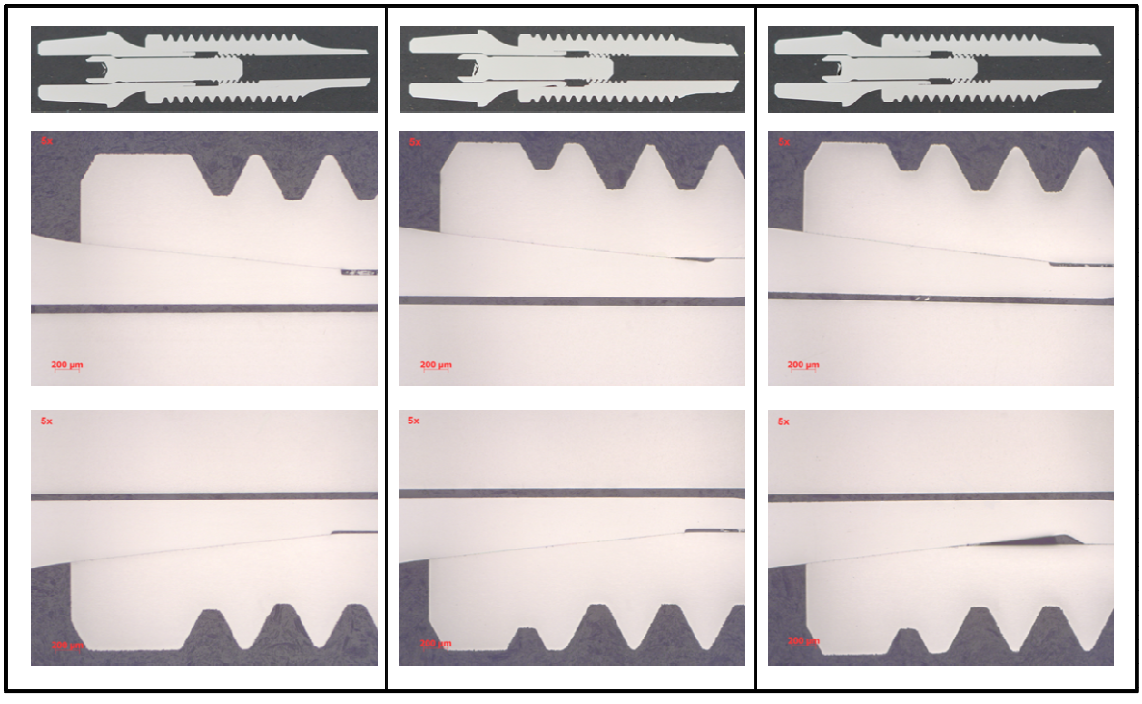

Figure 7 – Microscopy analysis of group E samples.

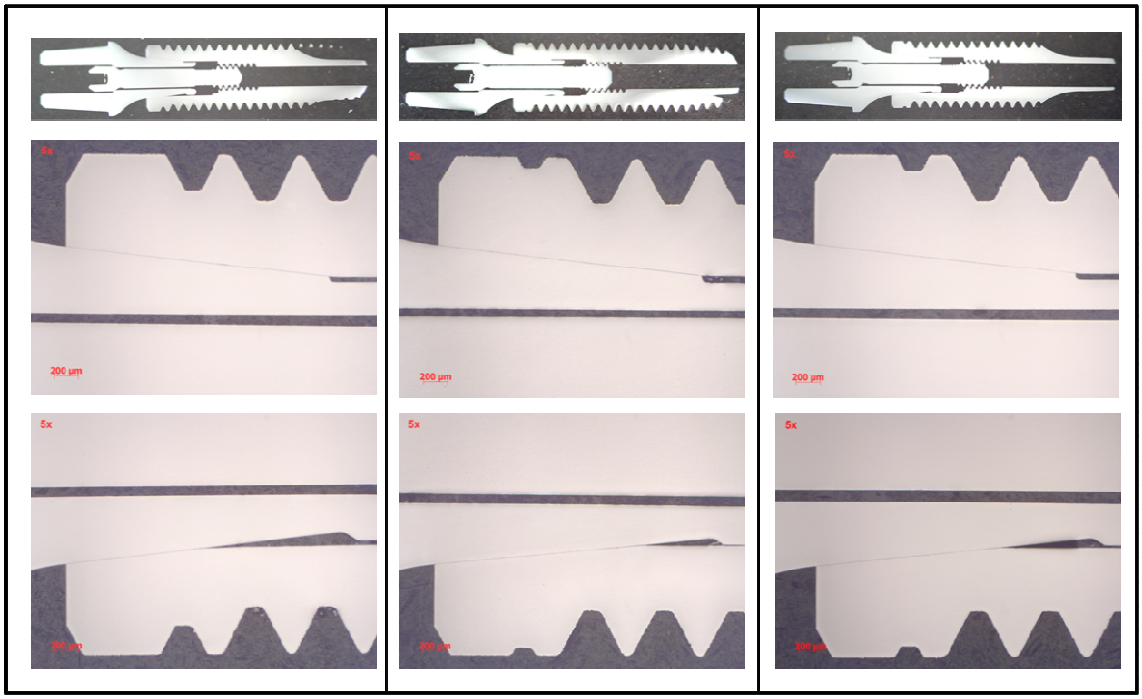

Figure 8 – Microscopy analysis of group C samples.

Discussion

The null hypothesis was rejected, since there were different gentian violet leak readings during the microleakage test between the groups.

To investigate specimen resistance to fatigue during approximately 3 years of simulated function, a target of 1 million cycles was defined (Kraisat et al., 2002). The loading frequency of the tests was 15 Hz. The load ranged sinusoidally between a nominal peak value and 10% of this value (in accordance with ISO 14801). The load, 116 N, was calculated according to equation $F=M/d$ sinα where F is force applied, M is torque applied during abutment tightening, d is lever length and α is the inclination of the specimen. For M=15Ncm, d=5mm and α=15°. This arrangement thus generated both a bending and a torqueing moment on the conical joints (Perriard et al., 2002). All the samples submitted to 1 million cycles achieved the end of the tests without failure.

The fatigue test had influence just on microleakage evaluation. After 80 minutes of test under 2 Bars pressure, the group submitted to fatigue (B) presented just one sample (25% of all samples) with gentian violet leaking, while the without fatigue test group (D) presented 3 samples (75%) with gentian

violet leaking. This means that the fatigue test, even with off-center load, seams to increase the lock and friction between the implant and the abutment.

In other study (Çehreli et al., 2004) this event of higher lock between implant and abutment was already observed since, after fatigue test, the Morse taper abutments had signs of slight wear on the morse-taper part, but not on the screw threads, which implies that the morse-taper indisputably carried most of the applied load and protected the abutment threads from overloading. The mechanical principles of taper connection were well discussed by previous studies (Merz et al., 2000; Bozkaya & Müftü, 2003) discussing the large contact pressure and resulting frictional resistance. In summary, in the case of taper Morse junction, the biting force acts in the direction of the abutment insertion, hence aids to secure the connection. This situation is in direct contrast to implants using screws where the biting force lowers the pretension in the screw (Bozkaya & Müftü, 2003). Although the apparent higher interface lock for group after fatigue, through the 3D measurements no change of height between the abutment and implant platform was noted.

In all implant systems, the implant-abutment mating design determines the mechanical integrity of the implant-abutment complex and rules joint strength and stability (Norton 1997; Binon 2000; Merz et al. 2000; Norton 2000; Khraisat et al.2002; Akça et al. 2003; Steinebrunner et al., 2008). Together with proper design of the occlusion and stable osseointegration, a reliable connection between implant and abutment is an important precondition for the appropriate functioning and stability of implant restorations (Norton, 1997).

In the present study, 1 million fatigue cycles with load applied in vertical direction off-center of implant had no negative influence in the integrity of Morse taper implant/2 pieces abutment assembly. While mechanical testing merely shows if and where a system will break, the non-destructive methods provide insight into the inherent mechanics of a given technical system. Another non-destructive method could be used in future studies to obtain meaningful results, such a non-linear Finite Element Method model.

Acknowledgements

The authors want to thank Neodent (Curitiba, Brazil) for its contribution to this research.

References

Akça, K., Çehreli, M.C. & Iplikçioglu, H. (2003) Evaluation of the mechanical characteristics of the implant–abutment complex of a reduced-diameter morse taper implant: a nonlinear finite element stress analysis. *Clinical Oral Implants Research* **14**: 444–455.

Albrektsson, T. (1988) A multicenter report on osseointegrated oral implants. *Journal of Prosthetic Dentistry* **60**: 75-84.

ASTM E407-07 - Standard Practice for Microetching Metals and Alloys

Binon, P. (2000) Implants and components. *International Journal of Oral & Maxillofacial Implants* **15**: 76–94.

Bozkaya, D. & Müftü, S. (2003) Mechanics of the tapered interference fit in dental implants. *Journal of Biomechanics* **36**: 1649-1658.

Burguete, R.L., Johns, R.B., King, T. & Patterson E.A. (1994) Tightening characteristics for screwed joints in osseointegrated dental implants. *Journal of Prosthetic Dentistry* **71**: 592-599.

Çehreli M.C., Akça, K., Iplikçioglu, H. & Sahin, S. (2004) Dynamic fatigue resistance of implant–abutment junction in an internally notched morse-taper oral implant: influence of abutment design. *Clinical Oral Implant Research* **15**: 459–465.

Cochran, D. (1996) Review: Implant I. In: Annals of Periodontology. Vol 1: 1996 World Workshop in Periodontics. Chicago: American Academy of Periodontology.

Dibart. S., Warbington, M., Su, M.F. & Skobe, Z. (2005) In vitro evaluation of the implant-abutment bacterial seal: the locking taper system. *International Journal of Oral Maxillofacial Implants* **20**: 732-737.

Gross, M., Abramovich, I. & Weiss, E.I. (1999) Microleakage at the abutment-implant interface of osseointegrated implants: a comparative study. *International Journal of Oral Maxillofacial Implants* **14**:94-100.

Haack, J.E., Sakaguchi, R.L., Sun, T. & Coffey, J.P. (1995) Elongation and preload stress in dental implant abutment screws. *International Journal of Oral Maxillofacial Implants* **10**: 529-536.

Hansson, S. (2003) A conical implant-abutment interface at the level of the marginal bone improves the distribution of stresses in the supporting bone. An

axisymmetric finite element analysis. *Clinical Oral Implants Research* **14**: 286-293.

Hernigou, P., Queinnec, S. & Flouzat Lachaniette, C.H. (2013) One hundred and fifty years of history of the Morse taper: from Stephen A. Morse in 1864 to complications related to modularity in hip arthroplasty. *International Orthopaedics* **37**: 2081-2088.

ISO 14801:2007 - Dynamic fatigue test for endosseous dental implants

Khraisat, A., Stegaroiu, R., Nomura, S. & Miyakawa, O. (2002) Fatigue resistance of two implant/abutment joint designs. *Journal of Prosthetic Dentistry* **88**: 604-610.

King, G.N., Hermann, J.S., Schoolfield, J.D., Buser, D. & Cochran, D.L. (2002) Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: a radiographic study in the canine mandible. *Journal of Periodontology* **73**: 1111-1117.

Mangano, C., Mangano, F., Shibli, J.A., Tettamanti, L., Figliuzzi, M., d'Avila, S., Sammons, R.L. & Piattelli, A. (2011) Prospective evaluation of 2,549 Morse taper connection implants: 1- to 6-year data. *Journal of Periodontology* **82**: 52-61.

McGlumphy, E.A., Mendel, D.A. & Holloway, J.A. (1998) Implant screw mechanics. *Dental Clinics of North America* **42**:71-89.

Merz, B.R., Hunenbart, S. & Belser, U.C. (2000) Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. *International Journal of Oral Maxillofacial Implants* **15**: 519-526.

Moser, W. & Nentwig, G.H. (1989) Finite-Element-Studien zur Optimierung von Implantatgewindeformen Implantatgewindeformen. *Z Zahnärztl Implantol* **5**: 29–32.

Norton, M.R. (1997) An in vitro evaluation of the strength of an internal conical interface compared to a butt joint design. *Clinical Oral Implants Research* **8**: 290–298.

Norton, M.R. (2000) In vitro evaluation of the strength of the conical implant-to-abutment joint in two commercially available implant systems. *Journal of Prosthetic Dentistry* **83**: 567-571.

Perriard, J., Wiskott, W.A., Mellal, A., Scherrer, S.S., Botsis, J. & Belser, U.C. (2002) Fatigue resistance of ITI implant-abutment connectors -- a comparison of

the standard cone with a novel internally keyed design. *Clinical Oral Implants Research* **13**: 542-549.
Sakaguchi, R.L. & Borgersen, S.E. (1995) Nonlinear contact analysis of preload in dental implant screws. *International Journal of Oral Maxillofacial Implants* **10**: 295-302.
Schwarz, M.S. (2000) Mechanical complications of dental implants. *Clinical Oral Implants Research* **11** Suppl 1: 156-8.
Steinebrunner, L., Wolfart, S., Ludwig, K. & Kern, M. (2008) Implant-abutment interface design affects fatigue and fracture strength of implants. *Clinical Oral Implants Research* **19**: 1276-1284.

3- CONSIDERAÇÕES FINAIS

Na Implantodontia moderna, para se definir sucesso em Implantodontia, pensa-se em estabilidade mecânica pilar/implante, estabilidade biológica dos tecidos adjacentes, estabilidade mecânica da prótese, integridade do implante e ausência de outras complicações técnicas. No entanto, frente às diferentes interfaces protéticas que se tem atualmente, deve-se esperar diferentes padrões e motivos de falhas. É sabido que a alta estabilidade da conexão cone Morse significativamente reduz a taxa de complicações protéticas. Em acompanhamento clínico de 2549 implantes cone Morse, entre 1 e 6 anos em função mastigatória, observou-se 0,37% de perda do componente protético (Mangano et al., 2011). Sistemas de implantes que dependem da pré-carga do parafuso para manter o abutment em posição parecem estar mais expostos a complicações protéticas, uma vez que forças resultantes de contatos oclusais (fisiológicas ou patológicas) podem exceder a força de união do componente ao implante e resultar na soltura ou fratura do parafuso, e, comsequentemente, do sistema (Merz et al., 2000; Steinebrunner et al., 2008).

As características da interface componente protético/implante influenciam não apenas o comportamento mecânico do sistema, mas também a resposta biológica adjacente ao implante. A estabilidade da interface, assim como a menor amplitude de micromovimentos, tem sido pontuada como responsável por favorecer a distribuição de tensões no osso (Hansson, 2003) e por diminuir a reabsorção da crista óssea periimplantar (King et al., 2002; Mangano et al., 2011).

Por ser uma interface cônica, parece que o carregamento mastigatório pode até resultar em maior embricamento entre o componente protético e o implant cone Morse. No presente estudo, observou-se menor microinfiltração em sistemas submetidos a fadiga e em estudo prévio, o evento de maior fricção entre as partes também foi notado por meio de sinais ao longo da porção cônica do componente (Çehreli et al., 2004).

Considerando que o cone interno do implante é o mesmo para os diferentes diâmetros de implante e as diferentes direções de carga que existem na cavidade oral, deve-se ponderar a seleção do diâmetro do implante para reabilitação de diferentes regiões da boca. No presente estudo, pôde-se notar

que sob carregamento axial, o diâmetro do implante é mandatório no nível de deformação horizontal que ocorre na região cervical. Nesse contexto, implantes com maior diâmetro externo e, consequentemente, maior parede de titânio ao redor do cone interno do implante, apresentam menor deformação e devem ser considerados para reabilitações unitárias em regiões posteriores, em caso de disponibilidade óssea.

Com o objetivo de buscar vantagens protéticas, algumas empresas propuseram a inclusão de indexador interno no implante cone Morse. Neste estudo, também avaliou-se se a inclusão do index poderia afetar o vedamento e a resistência do implante, uma vez que resulta na diminuição da área de contato na porção cônica implante/componente. A partir das metodologias de microinfiltração bacteriana e de resistência a fratura, observou-se que a presença do index não comprometeu o desempenho de implantes cone Morse.

Estudos futuros associando metodologias não destrutivas que permitam a predição da falha em implantes cone Morse podem cada vez mais refinar a indicação deste sistema que já tem uma taxa clínica de sucesso tão consolidada. O método de elementos finitos é uma das ferramentas que pode ser considerada para tais avaliações. No entanto, como é uma ferramenta totalmente alimentada pelo pesquisador no que tange a inclusão de propriedades mecânicas assim como a definição das condições de contato entre as peças, a simulação em elementos finitos do sistema cone Morse deve considerar o seu princípio mecânico de fricção na interface cônica e, consequente, proteção das roscas do parafuso do componente protético durante a distribuição de tensões (Merz et al., 2000). Muito tem-se que evoluir sobre a simulação de elementos finitos para implantes cone Morse, buscando a fidelidade com o que ocorre na prática. Um dos capítulos deste estudo buscou apresentar duas opções, com suas respectivas limitações, para a simulação correta da pré-carga em sistema cone Morse, considerando que a pré-carga nestes sistemas não fica restrita ao parafuso, como acontece em sistemas de implante hexagonais externos.

Como sugestões de estudos futuros, pode-se propor o aprofundamento em outras características da metodologia de elementos finitos aplicada ao sistema cone Morse, assim como acompanhamentos clínicos retrospectivos que demonstrem o resultado biológico da estabilidade mecânica deste sistema.

4- CONCLUSÕES

De acordo com os resultados obtidos nos estudos laboratoriais, pode-se concluir que:

1- O diâmetro influenciou a deformação nas paredes externa e interna na região cervical de implantes cone Morse;
2- A presença de indexador protético no fim do cone interno de implantes cone Morse não teve influência na infiltração bacteriana sob carregamento estático;
3- A presenção de indexador protético no fim do cone interno de implante cone Morse não reduziu a sua resistência à fratura;
4- Na simulação de pré-carga em implantes cone Morse não foi encontrada nenhuma diferença na distribuição das tensões ao longo da junção implante/ pilar, para ambos os métodos para simular essa condição;
5- Um milhão de ciclos de fadiga com carga aplicada axialmente fora do longo eixo do implante não influenciou negativamente a integridade de implante cone Morse montado com componente protético de parafuso passante.