Taís Alves dos Reis

Comportamento biomecânico de implantes odontológicos de diâmetro estreito

Biomechanical behavior of narrow diameter dental implants

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

Uberlândia, 2019

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Orientador: Prof. Dr. Flávio Domingues das Neves

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ATA

Ata da defesa de TESE DE DOUTORADO junto ao Programa de Pós-graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia.

Defesa de: Tese de Doutorado - COPOD

Data: 21/02/2019

Discente: **Taís Alves dos Reis (11513ODO016)**

Título do Trabalho: Comportamento biomecânico de implantes odontológicos de diâmetro estreito.

Área de concentração: Clínica Odontológica Integrada.

Linha de pesquisa: Implantodontia e Prótese sobre Implantes.

Projeto de Pesquisa de vinculação: Implantodontia e Prótese sobre Implantes.

As **quinze horas** do dia **vinte e um de fevereiro de 2019** no Anfiteatro do Bloco 4L, Anexo A, sala 23, Campus Umuarama da Universidade Federal de Uberlândia, reuniu-se a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em janeiro de 2019, assim composta: Professores Doutores: Karla Zancopé (UFU); Célio Jesus do Prado (UFU); Sérgio Rocha Bernardes (Faculdade Ilapeo); Gustavo Mendonça (University of Michigan); orientador(a) do(a) candidato(a) **Flávio Domingues das Neves.** O Prof. Dr. Sérgio Rocha Bernardes participou da defesa de Tese por meio de web-conferência desde a cidade de Curitiba - PR; o Prof. Dr. Gustavo Mendonça participou da defesa de Tese por meio de web-conferência desde a cidade de Michigan - USA; e os demais membros da Banca participaram *in loco.*

Iniciando os trabalhos o(a) presidente da mesa Dr. Flávio Domingues das Neves apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de argüição e resposta foram conforme as normas do Programa.

A seguir o senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos (às) examinadore (as), que passaram a argüir o(a) candidato(a). Finalizada a argüição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu os conceitos finais.

Em face do resultado obtido, a Banca Examinadora considerou o(a) candidato(a) (x)Aprovado(a).

Esta defesa de Tese de Doutorado é parte dos requisitos necessários à obtenção do título de Doutor. O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos às _18_ horas e _15_minutos. Foi lavrada a presente ata que após lida e achada conforme foi assinada eletronicamente pela Banca Examinadora.

Documento assinado eletronicamente por **Flavio Domingues das Neves**, **Presidente**, em 21/02/2019, às 18:17, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

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DEDICATÓRIA

Dedico este trabalho a Deus, nosso Pai Espiritual que nos guia pelos caminhos que devemos traçar. À minha família – minha fonte de amor e de paz, meu porto seguro, onde me amparo e me renovo.

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Á minha filha, Beatriz, a razão maior de todas as coisas. Minha pequena, que no começo era realmente pequena, agora tão crescida e tão independente. Amor maior e infinito. Obrigada por ter nos escolhido para esta jornada.

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Aos irmãos que também adotei: Lira, Maurício, Luciano, Rosana, Marina, Adalberto, Maria e Vitória. Aos sobrinhos queridos: Manuella e Rafael.

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À Faculdade de Odontologia da Universidade Federal de Uberlândia e ao Programa de Pós-Graduação. Esta também é minha casa, aqui me senti acolhida mais uma vez.

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"Ainda que eu falasse as línguas dos homens e dos anjos, e não tivesse amor, seria como o metal que soa ou como o sino que tine."

1 Coríntios 13:1

SUMÁRIO

RESUMO

As vantagens dos implantes estreitos são a substituição de elementos dentários de diâmetro cervical estreito, redução de cirurgias de enxertos ósseos ou necessidade de tratamento ortodôntico preliminar, procedimentos que poderiam aumentar os custos, o tempo de tratamento e a taxa de morbidade. Esta tese de doutorado possui quatro objetivos específicos: 1) Determinar as taxas de sobrevida e insucesso de implantes de diâmetro estreito unitários de acordo com a recomendação do fabricante, considerando todos os diâmetros ≤3,5mm por meio de uma revisão sistemática. Sete estudos tiveram seus dados extraídos. A taxa de sobrevida encontrada nesta revisão sistemática para implantes de diâmetro estreito unitários em áreas de pouco esforço mastigatório foi de 97%. Doze falhas foram descritas. 2) Avaliar o comportamento mecânico de dois diferentes sistemas de implantes cone Morse. Vinte implantes cone Morse, com diâmetro de 2,9 mm (FAC) e 20 implantes cone Morse de 3,5 mm de diâmetro (CM) foram divididos em dois grupos (n = 10), submetidos a teste de resistência à fratura, avaliação microscópica óptica da fratura, análise metalográfica da liga, análise de elementos finitos e teste de extensometria. A resistência à fratura foi estatisticamente diferente (p <0,001) entre os grupos FAC (225,0 ± 19,8 N) e CM (397,3 ± 12,5 N). A avaliação por microscopia óptica mostrou que os implantes foram fraturados na região de descontinuidade da interface pilar / implante, região do acúmulo de tensão na FEA. Análises metalográficas mostraram que os implantes do grupo FAC são compostos de liga de titânio-alumínio-vanádio. No teste de extensometria, não houve diferença estatística (p = 0,833) entre CM (1064,8 ± 575,04 μS) e FAC (1002,2 ± 657,6 μS). 3) Investigar o comportamento mecânico através do teste do limite de fadiga do implante de 2,9 mm de diâmetro. Além disso, investigar o efeito Morse de dois diferentes sistemas cone Morse: 2,9 mm de diâmetro (grupo FAC) e 3,75 mm de diâmetro (grupo CM) através do teste pull-out. A hipótese nula é que a resistência à tração dos componentes para os dois grupos é semelhante. Treze espécimes foram submetidos ao teste do limite de fadiga. Apenas cinco não falharam com a frequência e o número de ciclos determinados. Três deles não falharam com uma carga de 130N. No teste pull-out, houve uma diferença significativa entre os grupos FAC e CM (P <0.001). De acordo com o teste de fadiga, o implante Facility foi compatível com regiões de baixo esforço mastigatório, conforme indicado pelo fabricante. O melhor desempenho do grupo FAC no teste pull-out pode ser devido à sua porção cônica interna com 5º de angulação e à sua conexão Morse. 4) Descrever um caso clínico de agenesia de um incisivo lateral inferior, cuja indicação era a instalação de implante estreito e posterior reabilitação. A indicação de implantes estreitos deve ser feita de forma cautelosa, pois possuem características biomecânicas muito específicas, inferiores aos implantes de diâmetro regular. Algumas características do implante Facility podem ter favorecido seu desempenho mecânico dentro dos padrões clínicos aceitáveis para suas indicações.

Palavras-chave: implantes estreitos, biomecânica, revisão sistemática.

ABSTRACT

Advantages of narrow implants are replacement of small cervical diameter teeth, reduction or avoidance of bone grafts or preliminary orthodontic treatment. Moreover, bone grafts could increase costs, time of treatment and morbidity rate. This doctoral thesis has four specific objectives: 1) Determine survival and failure rates of single narrow diameter implants according to the manufacturers' recommendation, considering all diameters ≤3,5mm, by means of a systematic review. Seven studies had their data extracted. The survival rate found in this systematic review for single narrow diameter implants in low masticatory effort regions was 97%. Twelve failures were described. 2) Evaluate the mechanical behavior of two different Morse taper implant systems. Twenty Morse taper with frictional lock connection with 2.9 mm diameter (FAC), and 20 Morse taper implants, 3.5 mm diameter (CM) were divided into two groups (n=10) and were submitted to strength to failure test, optical microscopic evaluation of fracture, metallographic analysis of the alloy, finite element analysis and strain gauge test. The resistance to fracture was statistically different ($p<0.001$) between FAC (225.0±19.8 N) and CM (397.3±12.5 N) groups. The optical microscopic evaluation showed that implants fractured in the discontinuity region of the abutment/implant interface, the region of stress accumulation in FEA. Metallographic analysis showed that implants from the FAC group are composed of titanium-aluminum-vanadium alloy. In the strain gauge test, there was no statistical difference ($p=0.833$) between CM (1064.8±575.04 μS) and FAC (1002.2±657.6 μS). 3) Investigate the mechanical behavior through fatigue limit test of the 2.9mm diameter implant. Besides, it was investigated the Morse effect of two different Morse taper systems: 2.9mm diameter (FAC group) and 3.75mm diameter (CM group) through pull-out test. The null hypothesis was that the tensile strength of the components for the two groups were similar. Thirteen specimens underwent the fatigue limit test. Only five did not fail with the frequency and number of cycles determined. Three of them did not fail with a load of 130N. In the pull-out test there was a significant difference between the FAC and CM groups ($P<0.001$). According to fatigue test, the Facility implant was compatible with low masticatory effort regions, as indicated by manufacturer. The best performance of the FAC group in the pull-out test may be due to its internal conical portion with 5º of angulation and its Morse connection. 4) Describe a clinical case of agenesis of a lower lateral incisor, whose indication was the installation of a narrow implant and subsequent rehabilitation. The indication of narrow implants must be made with caution, since they have very specific biomechanical characteristics, inferior to the implants of regular diameter. Some features of the Facility implant may have favored its mechanical performance within the acceptable clinical standards for its indications.

Keywords: narrow implants, biomechanics, systematic review.

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Nas últimas décadas, o uso de implantes dentários vem melhorando progressivamente o planejamento para pacientes que possuem perdas totais ou parciais (Anitua *et al.,* 2010). A correta seleção do implante é crucial para o sucesso da reabilitação e o diâmetro do implante é um fator que deve ser considerado. Algumas situações específicas restringem a instalação de implantes de diâmetro regular (3,75mm) como rebordos alveolares severamente reabsorvidos, espaços mesio-distais estreitos ou reabilitação de elementos dentários com diâmetros cervicais estreitos, como incisivos inferiores (Froum *et al.,* 2007; Davarpanah *et al.,* 2000). Outras condições patológicas como periodontite ou inflamações de origem endodôntica, bem como a perda de elementos dentários podem resultar em defeitos ósseos severos, resultando em rebordos alveolares estreitos (Park *et al.,* 2010; Araújo & Lindhe, 2005; Fiorellini *et al.,* 2005). Em algumas situações clínicas, mesmo os implantes de 3,5mm de diâmetro não são suficientemente estreitos para instalação e posterior reabilitação. Em casos de grandes perdas ósseas no sentido vestíbulo-lingual, enxertos ósseos são indicados para recuperar volume ósseo (Davarpanah *et al.,* 2000). Entretanto, estes procedimentos mais invasivos aumentam custo, tempo de tratamento e morbidade. Além do mais, alguns pacientes preferem tratamentos um pouco mais conservadores (Carlsson & Omar, 2010; Narby *et al.*, 2008). Os implantes estreitos (com diâmetro menor que 3,5mm), portanto, podem apresentar benefícios em casos bem restritos como a substituição de elementos com diâmetro cervical reduzido - incisivos laterais superiores e incisivos inferiores - evitando enxertos ósseos e/ou tratamentos ortodônticos preliminares à sua instalação (Galindo-Moreno *et al.*, 2017; King *et al*., 2016; Lauritano *et al.,*2014).

Além da redução do diâmetro dos implantes, as conexões protéticas também evoluíram com o surgimento das conexões internas, como os hexágonos internos e cone Morse. Estas conexões representam importantes fatores na promoção de uma melhor distribuição de stress e manutenção de osso ao redor do implante (Zancopé *et al.*, 2017). Além disso, a utilização de ligas que

possuem alta resistência (como por exemplo a liga de Titânio-Alumínio-Vanádio -Ti6Al4V e a liga de Titânio-zircônia - TiZr) possibilitou a diminuição do diâmetro dos implantes. A liga de Ti6Sl4V é considerada mais compacta e mais resistente e por isso pode apresentar maior resistência e melhor manutenção de aposição óssea, especialmente em superfícies tratadas (jateadas ou superfícies de titânio tratadas com ácido) (Hyzy *et al.,* 2016). Alguns estudos apontam que esta liga combinada com estas superfícies tratadas pode melhorar a diferenciação de osteoblastos in vitro e melhorar o processo de osseointegração in vivo (Olivares-Navarrete et al., 2014). Além disso, superfícies hidrofílicas mantidas em solução isotônica de 0,9% de cloreto de sódio acelera a aposição óssea e também a interfase de contato osso-implante ao redor de implantes durante os estágios iniciais de formação óssea, resultando em um maior grau de osseointegração (Sartoretto *et al.,* 2017; Val *et al., 2017*).

Sabe-se que os óxidos de titânio possuem baixa solubilidade e formam um filme de óxido espontaneamente. No entanto, alguns pontos de inclusão e descontinuidade no filme fazem com que o implante apresente áreas não cobertas, aumentando a dissolução de íons metálicos da superfície do implante e consequentemente diminuindo a integração do implante de titânio. Para aumentar a estabilidade do implante metálico a longo prazo, modificações na superfície das ligas de titânio estão sendo realizadas. Em um estudo "*in vitro"* revestimentos biomiméticos de hidroxiapatita e titânio pulverizados com plasma foram aplicados na superfície de implantes de titânio comercialmente puro e de Ti6Al4V (Rahman *et al.,* 2016). A morfologia e a química da superfície foram estudadas por meio de microscopia eletrônica de varredura e espectroscopia fotoeletrônica de Raio-X respectivamente. Também foi estudado o comportamento eletroquímico e citotoxidade das superfícies cobertas por titânio pulverizado e hidroxiapatita. O estudo concluiu que ambas as superfícies aumentaram a resistência à corrosão e melhorou a citocompatibilidade.

No que diz respeito à citotoxidade da liga de Ti6Al4V, El Hadad *et al (*2018) conduziram um estudo que comparava citocompatibilidade "*in vitro"*, toxicidade sistêmica "*in vivo"* e avaliação de osseointegração em 2 ligas de titânio (Titânio- Nióbio e Titânio-Alumínio-Vanádio) cobertos por fosfato de cálcio. Os

testes de citocompatibilidade "*in vitro"* revelou alta citocompatibilidade para os implantes de Ti6Al4V, bem como para toxicidade nos estudos "*in vivo".* O potencial para osseointegração para ambos os grupos foi comparável.

A avaliação de resistência à corrosão, atividade antibacteriana e citotoxidade da liga de Ti6Al4V coberta por Cobre foram avaliadas por Guo *et al.,* 2017. Observações microestruturais revelaram que o Cobre fundiu completamente na liga Ti6Al4V, e apresentou-se na forma de Ti2Cu à temperatura ambiente. Com o aumento do teor de Cobre, a densidade da liga diminuiu gradualmente, e os microporos foram obviamente encontrados. Adicionalmente, semelhante à liga Ti6Al4V, as ligas contendo cobre também exerceram uma boa citocompatibilidade às células estromais da medula óssea (BMSCs) de ratos Sprague Dawley (SD). Com base nesses resultados, o estudo preliminar verificou que era viável a fabricação de ligas de Ti6Al4V-xCu por meio do processamento comercial de mistura de Ti6Al4V e Cobre em pó.

Apesar de implantes de diâmetro reduzido apresentarem muitas vantagens clínicas, algumas características biomecânicas e biológicas devem ser analisadas com cuidado. Quando nos referimos à implantes com diâmetro regular (3,75mm), o risco de fratura é de aproximadamente 2 para cada 1000 implantes instalados (Spachez-Peres *et al.,* 2010). Entretanto, esta informação não está bem esclarecida para implantes estreitos bem como outros importantes fatores clínicos como o local de instalação destes implantes, o momento de instalação de próteses, período de acompanhamento e tipo de conexão protética que podem influenciar em taxa de sobrevida e falhas destes implantes. Um estudo laboratorial investigou se implantes de peça única ou duas peças com diâmetro de 3,0mm podem apresentar tensão equivalente no que se refere à distribuição de carga oclusal sob carregamento e também avaliar a resposta do osso marginal (Ormianer *et al.,* 2012). Foram feitos desenhos em software de implantes de uma e duas peças restaurados com copings metálicos e instalados em modelos ósseos que variavam em dimensão, densidade e porcentagem de contato implante-osso. A análise por elementos finitos 3D simulou a carga oclusal para avaliar stress e tensão com relação ao desenho do implante e espessura do osso periimplantar, espessura do osso cortical, direção e

magnitude das forças oclusais e porcentagem do contato osso-implante. O stress e a tensão foram semelhantes em todas as condições experimentadas nestes implantes testados com dimensões equivalentes. O nível de stress no osso foi influenciado pela espessura do osso periimplantar e o diâmetro do implante. Apenas os implantes de peça única com 3,0mm de diâmetro em osso de baixa densidade apresentaram níveis de stress que podem afetar a estabilidade óssea marginal de forma prejudicial. Os autores concluíram que a distribuição de carga no osso foi influenciada pela espessura do osso periimplantar e pelo diâmetro do implante. Não houve influência nestas variáveis na avaliação de pilar-implante. Implantes estreitos de peça única devem ser limitados à ossos densos para minimizar a concentração de stress.

Por meio da extensometria, Castro *et al.,* (2015) avaliaram a deformação de diferentes implantes cone Morse (3,5mm, 4,0mm e 5,0mm, n=10) durante a aplicação de uma carga axial de 1500N e a deformação residual após a remoção da carga. Os valores de deformação das amostras foram gravados em dois tempos: na carga máxima (1500N) e 60 segundos após a remoção da carga. O implante de 5,0mm apresentou valor de deformação estatisticamente significante (650,5 μS ± 170,0) quando comparado com o grupo de implante de 4,0 mm (1170,2 μS ± 374,7) e o grupo de 3,5 mm (1388,1 μS ± 326,6) ($p < 0.001$), independente da presença de carga. Os valores de deformação diminuíram cerca de 50% depois da remoção da carga, independente do diâmetro do implante. O implante de 5,0mm demonstrou menor deformação na interface pilar/implante (943,4 μS ± 504,5) quando comparado com o grupo de 4,0mm de diâmetro (1057,4 μS ± 681,3) e o grupo de 3,5 mm de diâmetro (1159,6 μS ± 425,9) ($p < 0.001$). De acordo com os resultados deste estudo, os autores concluíram que o diâmetro influenciou a deformação ao redor das paredes internas e externas da região cervical dos implantes cone Morse e todos os implantes apresentaram valores de deformação clinicamente aceitáveis.

Em um estudo laboratorial, Wu *et al.,* 2016 avaliaram o stress e a tensão em implantes e osso por meio de análise de elementos finitos (AEF), extensometria e também a estabilidade do implante por meio do Periotest value (PTV). Os implantes utilizados eram de peça única (Nobel Direct) e de duas

peças (Nobel Replace) de 3,5mm de diâmetro. O pico de tensão medido na extensometria no osso foi 42% mais baixo para os implantes de duas peças do que para os implantes de peça única e no Periotest value, a estabilidade do implante foi levemente menor para os implantes de corpo único (PTV= -6) do que os implantes de duas peças (PTV= -5). Na análise de elementos finitos, o stress no implante e no osso foi 23% maior para o implante de corpo único. Os autores concluíram que implantes estreitos de peça única podem aumentar o stress e a tensão no osso periimplantar e aumentar o risco de perda óssea induzida por sobrecarga. Os autores concluíram também que o stress mecânico no implante é maior nos implantes estreitos de duas peças.

Um estudo laboratorial avaliou a força máxima no limite elástico (FLE) de implantes com conexão interna (IC, 3,5mm), com implantes hexágonos externos (REH, 3,75mm) e implantes hexágonos externos estreitos (NEH, 3,3mm) (n=10) (Carneiro *et al.,* 2016). Os implantes foram avaliados por meio de carga de flexão em cantilever utilizando uma máquina de ensaio universal. Os grupos foram avaliados qualitativamente em microtomógrafo com relação a mudanças na superfície do implante, pilar e arquitetura do parafuso. Os grupos REH (294,37 N) e IC (294,37 N) foram estatisticamente superiores em Fle do que o grupo NEH (189,16 N). Com relação à tensão, não houve diferença estatística entre os grupos. Entretanto, houve um maior número de fissuras e mais fraturas no grupo NEH. Os implantes do grupo IC (implantes estreitos) não apresentaram redução do limite elástico quando comparado com os implantes do grupo REH. Entretanto, a redução de 0,45mm do diâmetro do implante na conexão hexagonal diminuiu significantemente a sua resistência.

Muitos estudos relatam a instalação de implantes estreitos com diferentes técnicas como carga imediata, com ou sem enxertos autógenos ou por meio de cirurgias guiadas (El- Gammal *et al.,* 2014; Sohn *et al.,* 2011; Anitua *et al*., 2010; Degidi *et al.,* 2009a; Romeo *et al*., 2006). As taxas de sobrevidas foram satisfatórias, tanto em médio quanto a longo prazo (de 96,9% até 100%) com período de acompanhamento variando de 1 (um) a 7 anos (Zémbic *et al.,* 2011; Vigolo *et al.,* 2004). Alguns estudos relatam fratura do corpo do implante quando estes não são instalados de acordo com a recomendação do fabricante (Bordin

et al., 2017; Yaltirik *et al*., 2011; Zinsli *et al*., 2004). Estes dados reforçam o fato de que alguns destes implantes estreitos não podem ser instalados em qualquer área, diferente do que observamos com implantes de diâmetro regular. Além do mais, é de extrema importância que sejam testados mecanicamente antes de colocados em função.

Em reabilitações unitárias os estudos relatam taxas de sucesso que variam de 94,2% até 100% com tempos de acompanhamento de 1 até 5 anos (King *et al.,* 2016; Oyama *et al.,* 2012; Galindo-Moreno *et al.,* 2012; Zembic *et al*., 2012; Sohn *et al*., 2011; Degidi *et al*., 2009a; Vigolo et al., 2000). Estes estudos instalaram implantes de 2,9mm e 3,0mm em áreas de pouco esforço mastigatório com perdas ósseas que variam de -0,065mm até -0,8mm.

Estudos que avaliaram overdenture sobre implantes estreitos (2,5mm e 3,3mm) relataram sobrevida dos implantes de 95,5% até 100% (Müller *et al*., 2015; Quirynen *et al.,* 2014; Zweers *et al*., 2015; Jofre *et al.,* 2013; Al-Nawas *et al*., 2012; Morneburg & Pröschel 2008). O tempo de acompanhamento destes estudos foi de 1 até 6 anos. A menor taxa de sobrevida encontrada (95,5%) foi descrita no estudo de Morneburg & Pröschel (2008) e também foi o maior tempo de acompanhamento descrito (6 anos). A perda óssea marginal descrita nos estudos de Al- Nawas *et al.,* (2012); Zweers *et al*., (2013); Quirynen *et al.,* (2015) e Müller *et al.,* (2015) variou entre -0,16mm e -0,78mm.

Alguns estudos entretanto, utilizaram implantes estreitos para reabilitações unitárias, parciais e totais (Markovic *et al.,* 2017; Golab *et al*., 2016; Anitua *et al*., 2015; Al-Nawas *et al.,* 2015; Lauritano *et al*., 2014; Fanali *et al*., 2012; Yaltirik *et al.,* 2011; Arisan *et al.,* 2010; Anitua *et al.,* 2010; Degidi *et al*., 2009b; Romeo *et al.,* 2006; Vigolo *et al*., 2004; Zinsli *et al.,* 2004; Hallman 2001). Os diâmetros utilizados foram de 2,5mm, 2,9mm, 3,0mm, 3,3mm, 3,4mm e a taxa de sobrevida foi descrita entre 80,5% até 100% com acompanhamento de 1 até 10 anos. A perda óssea marginal foi de -0,35mm até -1,5mm. Estes estudos são mais heterogêneos e por este motivo, existe uma maior variação dos dados apresentados. Apenas o estudo de Vigolo *et al*., 2004 descreveu que as próteses

parciais fixas estavam unidas à implantes de diâmetro regular, o que pode ter favorecido a taxa de sobrevida descrita (95,3%).

Algumas revisões sistemáticas da literatura descrevem taxas de sobrevida para implantes estreitos que variam de 94,7% (Brida & Almas 2013) até 100% (Klein *et al.,* 2014) com diâmetros dos implantes de 1,8mm até 3,5mm. Entretanto, esses dados são muito escassos quando avaliamos implantes com diâmetro <3,0mm no que diz respeito às suas taxas de falhas e de sobrevidas em estudos clínicos controlados, principalmente com longos períodos de acompanhamento. Esses dados poderiam elucidar como estes implantes se comportam clinicamente e qual a melhor indicação principalmente para casos limítrofes.

Atualmente, estão disponíveis no mercado implantes de 3,3mm com a liga de Titânio-zircônia (Roxolid, Straumann Institut Straumann® AG, Basel, Switzerland). Alguns estudos avaliaram parâmetros clínicos deste implante com acompanhamento que varia de 1(um) até 5 anos (Markovick *et al.,* 2017; Müller *et al.,* 2015; Al-Nawas *et al.,* 2015; Quirynen *et al.,* 2015; Al-Nawas *et al.,* 2012). A taxa de sucesso destes implantes variou de 95,8% com 5 anos de acompanhamento (Müller *et al.,* 2015) até 100% com um ano de acompanhamento (Markovick *et al.,* 2017). Nenhum dos trabalhos acima relatou fratura do implante. Al-Nawas *et al* (2015) relataram a perda de 10 implantes de TiZr com 2 anos de acompanhamento, sendo nove deles antes da restauração final (próteses unitárias cimentadas, próteses parciais fixas e overdenture). Neste trabalho, 357 pacientes receberam 603 implantes – 68,8% dos pacientes receberam apenas implantes de TiZr e 31,2% receberam pelo menos 1 (um) implante de TiZr e também implantes de titânio. A taxa de sucesso foi de 97,6% em 2 anos de acompanhamento. A perda óssea marginal foi menor que 1mm em 11,2% dos implantes instalados e não foi observada perda óssea em 81,2% dos implantes. Em um estudo prospectivo “Split-mouth”, Markovick *et al.,* 2017 acompanharam pacientes que tomavam anticoagulantes com edentulismo parcial que requeriam pelo menos 2 implantes para reabilitações parciais ou edentulismo total para avaliar taxa de sucesso e sobrevida de implantes de TiZr de 3,3mm de diâmetro com superfície SLA active hidrofílicas ou hidrofóbicas. A

taxa de sucesso foi de 100% com 1(um) ano de acompanhamento. Alguns trabalhos compararam sucesso e perda óssea marginal dos implantes de TiZr com os implantes de titânio Grau IV (Müller *et al.,* 2015; Quirynen *et al.,* 2015; Al-Nawas *et al.,* 2012). Com relação à perda óssea marginal, nenhum dos trabalhos citados encontrou diferença estatística entre os implantes. A menor perda óssea foi relatada no estudo de Al-Nawas *et al.* (2012) com acompanhamento de 1 ano: -0,34 ± 0,54mm para os implantes de TiZr e -0,31± 0,56mm para os implantes de titânio Grau IV. Com um acompanhamento de 5 anos, Müller *et al.,* 2015 descreveu perda óssea de -0,60 ± 0,69mm para os implantes de TiZr e -0,61 ± 0,83mm para os implantes de Titânio Grau IV. A taxa de sucesso dos implantes de TiZr variou de 98,7% até 98,9% e a dos implantes de titânio Grau IV variou de 97,3% até 97,8%. Com esta mesma liga de TiZr(Roxolid) a Straumann lançou o implante com 2,9mm de diâmetro.

Em 2013 a Neodent lançou o Facility (Neodent, Curitiba, PR, Brasil), um implante estreito com 2,9mm de diâmetro, que foi desenvolvido para áreas com grandes perdas ósseas (inclusive para reabilitações implanto-retidas e mucosuportadas que apresentam grande reabsorção no sentido vestíbulo-lingual – overdenture) e para áreas de pouco esforço mastigatório (como incisivos laterais superiores e incisivos inferiores). Sua principal característica é uma interface com conexão protética Morse, sem parafusos internos, com o objetivo de preservar sua resistência e ao mesmo tempo evitar o estreitamento das paredes do implante, bem como sua liga de titânio grau V (Ti6Al4V) que é mais compacta e mais resistente. O implante Facility está disponível no mercado com duas superfícies: Neoporos (hidrofóbica) e Aqua (hidrofílica - lançado em 2015).

O objetivo geral do presente estudo foi avaliar as características biomecânicas de implantes de diâmetro estreito (2,9mm, Facility, Neodent).

Os objetivos específicos são:

1) Determinar a taxa de sobrevida e falhas de implantes estreitos (≤ 3,5mm) instalados em áreas de pouco esforço mastigatório (incisivos laterais superiores e incisivos inferiores, de acordo com a recomendação do fabricante) por meio de uma revisão sistemática da literatura.
2) Avaliar o comportamento mecânico de dois diferentes sistemas de implantes dentários cone Morse de diâmetro estreito: implantes com conexão protética Morse de 2,9mm de diâmetro com angulação de 5° da porção cônica interna (FAC) e sem parafusos internos; e implantes cone Morse com 3,5mm de diâmetro com 11,5° de angulação da porção cônica interna (CM). A hipótese nula é que não existe diferença na resistência à fratura e deformação das paredes externas destes dois tipos de implantes estreitos.
3) Investigar o comportamento mecânico por meio do limite de fadiga de implantes de diâmetro 2,9mm (Facility; Neodent) sob carregamento (teste dinâmico) de acordo com a ISO 14801:2007. Além disso, o grupo de estudo pesquisou o efeito Morse de dois diferentes sistemas: implantes Facility com 2,9mm de diâmetro (Neodent, Curitiba, Curitiba, PR, Brasil) (FAC) e implante cone Morse Titamax CM 3,75 mm (Neodent, Curitiba, Curitiba, PR, Brasil) (CM) por meio do teste de pull-out. A hipótese nula é de que a resistência à tensão dos componentes dos grupos descritos acima seja similar.
4) Descrever um caso clínico de agenesia de um incisivo lateral inferior, cuja indicação é a instalação de implante estreito e posterior reabilitação.

CAPÍTULO 1 – ARTIGO 1

Reis TA, Barros JHL, Karam FK, Zancopé K, Neves FD. Survival rate and failures of narrow diameter dental implants for single rehabilitations: a systematic review. Int J Oral Maxillofac Implants – Artigo enviado

ABSTRACT

Advantages of narrow implants are the replacement of small cervical diameter teeth, reduction or avoidance of bone grafts or preliminary orthodontic treatment. Moreover, bone grafts could increase costs, time of treatment and morbidity rate. These facts could lead some patients to withdraw the treatment. The purpose of this systematic review was to determine survival and failure rates of single narrow diameter implants according to the manufacturers' recommendation, considering all diameters ≤3,5mm. We conducted a search at electronic databases (Pubmed, EMBASE and Cochrane Database of Systematic Reviews) up to January 2018. The search terms used were "narrow-diameter dental implants" OR "one-piece implants" OR "small-diameter implants" OR ''narrow'' [tiab] OR ''small diameter'' [tiab] OR ''mini'' [tiab]. The PRISMA flow diagram depicts the flow of information through the different phases. An initial electronic search identified 131 studies and manual searching process identified 16 studies. After titles and abstracts were read and all duplicates removed, the full texts of 35 studies were obtained. Articles that did not meet the inclusion criteria were excluded, leaving seven for data extraction. Two studies were retrospective and five were prospective studies. The survival rate found in this systematic review for single narrow diameter implants in areas of low masticatory effort was 97%. Twelve failures were described. During the complete reading of texts, fractures of narrow implant bodies were found when they were installed in posterior regions, even with short follow-up periods. These studies were excluded, according to exclusion criteria and highlight the importance of following the manufacturer's recommendation.

Keywords: dental implants, review, survival rates.

INTRODUCTION

Implants with 3,75 mm in diameter were used with excellent long-term benefits and are considered standard-diameter implants.[1,2,3] However, the development of Implantology must be seen in conjunction with clinical necessities. Given its proven success, this type of implant is also used for partial and single rehabilitations[4,5] in most areas, types, quantity and quality of bone.[6] Some borderline cases could not be treated with standard-diameter implants, especially in areas with considerable vestibule lingual bone loss and small mesio-distal spaces.[7] For vestibule lingual bone loss cases, bone graft is indicated.[8] However, this procedure could increase cost, time of treatment and morbidity rate. Besides, some patients prefer more conservative options.[9,10] Implants with a reduced diameter offer some benefits in these cases. It is attested that the main advantages of narrow implants are the replacement of small cervical diameter teeth (e.g. lateral incisors), reduction or avoidance of bone grafts or preliminary orthodontic treatment.[5,11,12] These indications could benefit patients that are not willing to undergo more invasive procedures for standard implant placement.

Therefore, several manufacturers have introduced narrow implants to the market (<3,5mm) with the main objective to address the clinical difficulties cited above.[5,12-17] Some in vitro studies described some limitations related to small implant diameters.[18] Until now, the indications of narrow implants are limited to low effort areas (such as superior lateral incisor, inferior incisors and under overdenture). Thus, narrow implants (smaller than 3,0mm) should not be indicated to all areas.[19,20-22] Perhaps the next stage on implant research might be increasing their indication, with the manufacturing more resistant narrow implants.

Although reduced-diameter implants present several clinical advantages, some biomechanical and biological characteristics must be analyzed carefully. Regarding standard implants, the estimated risk of fracture is approximately 2 per 1,000 in the mouth.[23]However, this information is still unclear for narrow implants as well as other important issues such as location of the narrow implant installation, moment of loading, follow-up period, and type of prosthetic connection that may influence the survival and failure rates of these implants. Thus, the main objective of this systematic review was to determine the survival and failure rates of narrow implants installed in areas of low masticatory effort (superior lateral incisor, inferior incisors – according to the manufacturers' recommendation).

MATERIALS AND METHODS

Search strategy and eligibility criteria

We conducted a search at electronic databases (Pubmed, EMBASE and Cochrane Database of Systematic Reviews) up to January 2018. This search was conducted by two researchers (J.H.L.B. and T.A.R), using PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analysis) to carry out the systematic review. PRISMA is “an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses”. This can ensure the quality of the collected data and that the literature search was carried out in a logical manner.

A manual search was also conducted covering relevant studies from 2012 to January 2018 in some major implant journals: European Journal of Inflammation, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, Nigerian Medical Journal, The International Journal of Prosthodontics, The International Journal

of Oral & Maxillofacial Implants, European Journal of Oral Implantology, Journal of Dentistry, Tehran University of Medical Sciences, BMC Oral Health.

The search terms used were “narrow-diameter dental implants” OR “one-piece implants” OR “small-diameter implants” OR ‘‘narrow’’ [tiab] OR ‘‘small diameter’’ [tiab] OR ‘‘mini’’ [tiab].

The eligibility criteria were based on the PICOS study design: patient population or disease being addressed (P), interventions or exposure (I), comparator group (C), outcome or endpoint (O), and study design chosen (S).[24]

Patient or population**:** patients rehabilitated with narrow implants in areas of low masticatory effort, with single prosthetic spaces in maxilla and/or mandible. No bounding criteria were imposed for patients with systemic disease and/or risk factor for any disease, as well as age interval. Surgeries for bone gain were not allowed.

Intervention: studies using implant with small diameter (≤ 3.5 mm) with no restriction to implant length.

Comparison: studies may compare their results for narrow implants to standard ones. Studies that present this information could be included in this review as long as the results are presented separately – survival and failure rates for small and standard diameters.

Outcome: The survival and failure rates for narrow implants installed in areas of low masticatory effort.

Study type: Prospective and retrospective clinical studies that evaluated survival and failure rates for implants with diameter ≤ 3,5 mm and a follow over at least 1 year.

Afterwards, the focal question was formulated: Do the narrow implants used to rehabilitate patients with single prosthetic spaces in areas of low masticatory effort in

maxilla and/or mandible have similar survival and failure rates compared to standard ones?

Data extraction

At least two reviewers (J.H.L.B. and T.A.R), using a standardized form, performed data extraction for each eligible study. The following variables were extracted from each study: Title; Authors; Year; Aim; Restoration Delivery; Design; Technique; Diameter; Length; Type of one-piece implant; Surface characteristics; Number of patients; Age range; Mean age; Number of implants; Location; Commercial trademark; Restoration Type; Type of fixed abutments; Bone loss; Follow up; Survival/ success; Failures; Dropouts.

Inclusion criteria

The inclusion criteria were: articles published in the English language, studies that were conducted in human patients, narrow dental implants (≤3,5mm), at least one year of follow up and studies that report failure and success rate for single restoration in areas of low masticatory effort. The articles presenting one or more of the following characteristics were excluded: studies with animals, cohort studies, case/report series, review articles, insufficient follow up (1 year) and studies that placed their implants in posterior areas, with immediate or delayed load.

Potential articles were independently reviewed by two researcher**s** (J.H.L.B. and T.A.R) primarily by the title and abstract and, later, through the reading of the full text. When disagreement occurred between the two examiners, final decision on the included articles was made by mutual agreement of the two examiners.

Risk of bias assessment

The Newcastle-Ottawa (NOS) scale was used to report any potential risk for bias. This scale is based on four specific components that define the quality of the studies and assess the risk of bias. The criteria used were the following: patient selection, comparability, exposure, and outcome. Two implantology specialist (F.K.K. and J.H.L.B) reviewers evaluated all of the selected studies.

RESULTS

An initial electronic search identified 131 studies (Figure 1) and the manual searching process identified 16 studies (total 147 studies). The duplicates were removed, resulting in 139 studies. After the titles and abstracts were read, the full texts of 35 studies were obtained. The articles that did not meet the inclusion criteria were excluded (28 Studies), leaving 7 (seven) for data extraction (Table I).

Description of studies

Two studies were retrospective and five were prospective studies. All studies accumulate more than 3 points after using the NOS, demonstrating medium or high risk of bias. This systematic review included studies that analyzed 405 implants and 12 failures were described. The survival rate was 97% for single narrow implants installed in areas of low masticatory effort (Table II). The follow-up period was heterogeneous, ranging from 1 year to 7 years (84 months).

Table III presents diameter, number of implants and failures and survival rate of the studies included in this study.

Regarding implant installation site, a classification was also made: implants installed only on the maxilla, only on the mandible, on both jaws (maxilla and mandible) (Table IV). One hundred fifty-seven implants were installed on the maxilla[7,11] with a survival rate of 97,5%. Studies that installed their implants on both jaws[12,17,20,25,26] added up to 248 narrow implants with a survival rate of 96,8%.

With respect to load in the narrow implants, three studies[7,17,25] installed 105 implants with immediate load, with a survival rate of 99%. Five studies[7,11,12,20,26] included in this study installed 300 implants with delayed load, with a survival rate of 96,3% (Table V). One study, however, installed 60 implants, 30 with immediate load and 30 with delayed load and no loss.[7]

The number of failures, commercial trademark, follow-up periods, location of the implants, failures and reasons for failures are described in table VI. One author described the failures of their study as poor bone quality at the recipient site and occlusal problems in five implants.[26] This failure was observed more frequently. Four cases were lost due to insufficient healing.[11,12] Two implants were lost due to periimplant infection.[11,12]. One study mentioned only the number of failures but did not mention the reasons for them.[17] Three studies reported no failures. [7,20,25]

The articles included in this study and all the variables extracted are described in Table VII.

DISCUSSION

A major difficulty for this review was the heterogeneity of concepts to determine what is considered a narrow implant in literature. Different denominations are

found in literature for narrow implants and a didactic classification in groups according to the implants diameter was proposed.[32] According to this classification, implants ranging in diameter from 3,3mm to 3,5mm are classified as “narrow implants”, implants whose diameters vary from 2,9mm up to 3,2mm are classified as “ultra-narrow implants”, and the implants with <2,9mm in diameter are classified as “mini implants”. In this systematic review, we tried to use this classification for the included studies. However, we were unable to use this rating because we could not find any study that met the inclusion criteria to be classified as “narrow implants” and “mini implants”. Besides that, this classification could be important to determine the survival rate of narrow implants, comparing the results between them. On the other hand, we understand that perhaps this classification is no longer so relevant because alloys that are more resistant have been released on the market. Thus, narrower implants may be more resistant, as it is the case of Roxolid (Straumann, Villeret, Switzerland).

This systematic review evaluated narrow implants (<3,5mm) for single rehabilitation in low masticatory effort areas and the studies included presented diameter implants that vary from 2,9mm to 3,25mm. Therefore, we can present reliable results only for these diameter ranges (survival rate of 97%). It is interesting to analyze this percentage because we believe that it represents the clinical reality of survival rate when narrow implants are installed according to the manufacturers' recommendation. This was a strong goal set for this systematic review because single rehabilitations are a major challenge for rehabilitation with narrow implants and maybe the next stage on implant research may be increasing its indication, manufacturing more resistant narrow implants.

Another variable that can interfere with the survival rate is the follow-up period. The survival rate of the studies with one or two years of follow-up presented survival

rates varying from 95,9% to 100%.[11,17,20,25] Greater follow-up (up to 3 years) presented survival rates varying from 94,7% to 100%.[7, 12,26] We emphasize that a short follow-up period may give a distorted prediction in relation to survival rate. The data would be more reliable with a follow-up period greater than 5 years.

The most frequent failure described in this systematic review was poor bone quality at the recipient site and to occlusal problems [26]. There was also a difficulty regarding failure interpretation. One study[17] mentioned only the number of failures but did not mention the reasons for them. Periimplant infection was described for two implants.[11,12] Four implants were lost due to insufficient healing.[11,12] An interesting observation is that this term could be a subjective manner to describe osseointegration failures. It seems that there is a lack of consensus around some terms used to describe osseointegration failures (insufficient healing, continuous radiolucency around the implant, lack of integration). Some studies do not mention the causes of failures in a clear form, misestimating how many implants are lost because of osseointegration failures, for instance.

One exclusion criteria adopted in this systematic review needs to be discussed. According to exclusion criteria defined for this systematic review, seven studies were excluded because they installed single narrow implants in posterior regions.[16,27-31,33] Although some of these articles[16,27,31] presented a 100% survival rate, they installed narrow implants up to premolars, overestimating the manufacturer's indication. Their follow-up period ranges from one to five years. Other two studies[28,30] that were excluded from our systematic review merit attention. One study [28] described the fracture of two implants in a 5-year follow up period. Eight 3,3mm diameter implants were installed in the molar region of the maxilla, an area of great masticatory effort, which could be the

reason for the failure. The survival rate was 62,5%. One study described that the reduction of 0,45mm diameter in external hexagon has significantly diminished the elastic limit and 3,3mm hexagon diameter implants present a greater number of fissures and more fractures when compared to 3,5 mm diameter hexagon implants.[18] The other study that described one fracture[30] in maxillary premolar area with a 6-year follow-up. In this study, seventeen implants were used for a single restoration and only this failure was described over a 10-year follow-up period (94,1% of survival rate). These results lead us to believe that narrow implants installed in posterior regions and with greater follow-up period (greater than 5 years) may fracture, and this could be attested in the studies cited above. In this review, no fractures were described even with a greater follow-up period in some studies (more than 3 years) maybe because the implants were installed in a low effort area. Interestingly enough, those occurrences observed in the follow-up period for narrow implants are different from what it is observed for standard diameter implants. Standard implants present a greater bone loss in the first year and in the second year smaller than in the third year. Perhaps the marginal bone loss observed for standard diameter implants is one of the most relevant measures to evaluate their success. However, in this review, we observed that narrow implants tend to fail with more than five years of follow-up, especially when we consider fractures of the implant bodies along with the installation in posterior region. This fact heightens caution when evaluating the survival rate and failures of several studies with only one year of follow-up or that installed implants in posterior region.

In this review, two studies installed their implants only in the maxilla.[7,11] The other studies installed their implants in both jaws.[12, 17, 20,25,26] Since the articles that installed

implants in both jaws do not specify the number of implants installed separately, it was impossible to discuss the survival rate by region of installation.

A difference in loading aspects was detected. The studies state a tendency to immediate loading. However, most studies present implants installed by delayed load. [7,11,12,20,26] In one study[7] 60 narrow implants were installed, 30 with immediate load and 30 with delayed load with a follow up period of 36 months and there no failures reported, resulting in a survival rate of 100%. In this review, the survival difference related to the immediate or delayed load was 2,7%. (99% and 96,3% respectively

The present systematic review presents a survival rate for narrow implants (≤3,5mm) of 97%. Another systematic review described a survival rate for implants <3,0 mm between 90,9% and 100%, the implants ranging from 3,0mm to 3,25mm presented a survival rate between 93.8% and 100%. Finally, the implants ranging from 3,3mm to 3,5mm presented a survival rate between 88,9% and 100%. However, it is remarkable that the group with greater diameter presented the greater survival interval.[34] Our results are among the percentages presented in this study for diameters 2,9 up to ≤3,2mm. Another systematic review evaluated the survival rate of mini implants (1,8 mm to 2,9 mm) and the survival rate was 94,7%. [35]

The authors of this review highlight that the presented results must be interpreted with caution because the studies are very heterogeneous, according to NOS scale. Due to the presence of different systems and diameters for narrow implants, the attempt of a meta-analysis could send incorrect information to clinicians regarding the use of narrow implants. Moreover, the studies presented a medium or high risk of bias. That is the reason a meta-analysis was not made. Moreover, it would be interesting to have studies with

more information available, since that would enable further understanding of major issues regarding narrow implants.

CONCLUSION

Given the importance of this issue, narrow implants should be evaluated according to the categories (groups). In this review, it was possible to define the survival rate only for implants with diameter 2,9 up to ≤3,2mm. This systematic review described a survival rate of 97% of single narrow implants (≤3,5mm) installed in regions of low masticatory effort, attesting that narrow implants have a survival rate compatible with current techniques, when the manufacturer's recommendation is followed. Twelve failures were described. Four implants were lost due to insufficient healing and two were lost due to infection. Even with short-term follow-up, fractures of implants installed in the posterior region were observed in the excluded studies, reinforcing the need to comply with the manufacturers' guidelines. More clinical studies are necessary so that the questions concerning narrow implants failures can be elucidated.

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The authors of this study attest that there is not conflict of interest.

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FIGURE

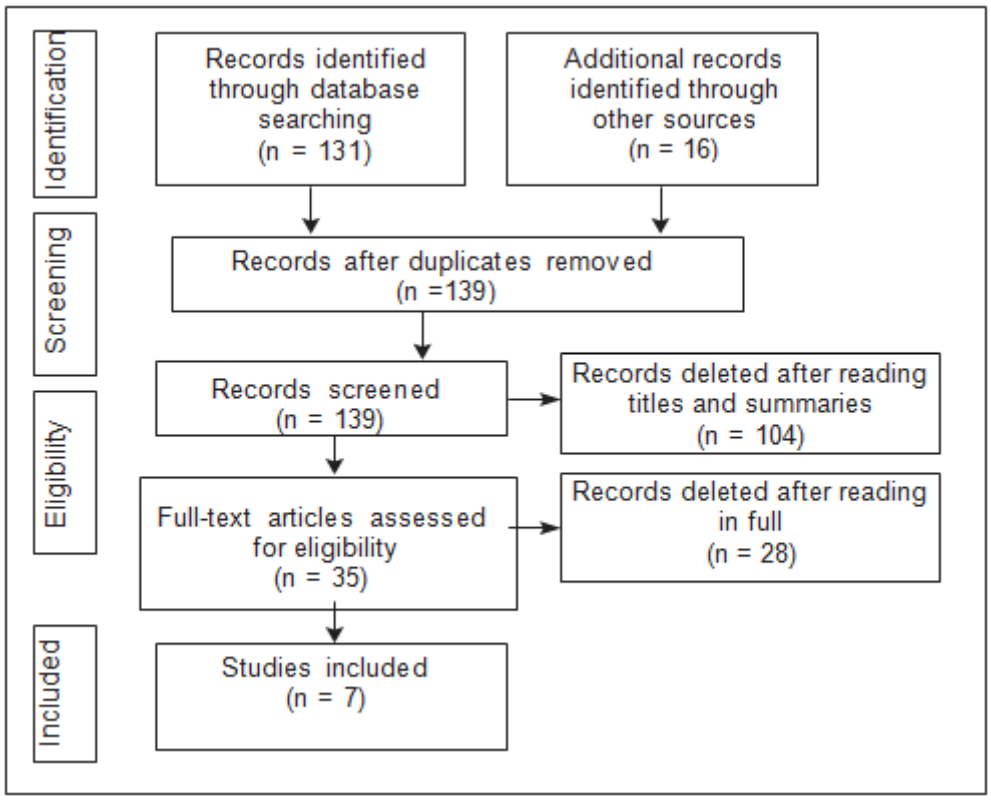

Fig. 1. Flowchart of the article eligibility process.

Table I . Exclusion of 28 full-text articles based on predetermined exclusion criteria.

Article Exlcuded	Exclusion Criteria Applied
HEIJDENRIJK et al. (2006) **CARICINI, (2012)** **ANITUA et al. (2016)**	Implant studies with a diameter greater than 3,5 mm.
MARKOVIC et al. (2016) **GOLAB et al. (2016)**	Describe rehabilitation of total and partial cases
SENNERBY et al. (2008)	Describe success rate of implants for two-stage implants and immediately/early loaded implants.
SATO et al. (2014) **BAER et al.(2013)** **FINNE et al. (2012)** **HAHN et al. (2007)** **OSTMAN et al. (2007)** **HARTMAN et al. (2004)** **ARISAN et al. (2010)** **BÖMICKE et al. (2017)** **FROUM et al. (2017)**	Studies that describe different diameters, but did not report the survival rate separately by diameter.
LAURITANO et al. (2014) **AL-NAWAS et al. (2015)** **HALLMAN et al. (2001)** **ANITUA et al. (2010)** **CABRERA-DOMINGUES et al. (2017)** **JACKSON et al. (2017)**	Studies that does not present success and failure rates separately for single restoration. .
ZINSLI et al. (2004) **YALTIRIK et al. (2011)** **ROMEO et al. (2006)** **EL-GAMMAL et al. (2014)** **SOARDI et al. (2012)** **VIGOLO et al. (2000)** **FANALI et al. (2012)**	Studies that placed narrow implants in posterior region.

Table II – Global survival rate of the narrow implants.

Authors	Nº of implants	Nº of failures	Survival Rate
King et al. (2016) Zembic et al. (2011) Sohn et al. (2011) Degidi et al. (2009) Galindo-Moreno et al. (2012) Oyama et al. (2012) Vigolo et al. (2004)	405	12	97%

Table III – Diameter, number of implants and failures and survival rate of the studies.

Author	Diameter	No of implants	No of failures	Survival rate
Vigolo et al. (2004)	2,9 and 3,25	94	5	94,7%
Degidi et al (2009)	3,0	60	0	100%
Sohn et al (2011)	3,0	18	0	100%
Zembic et al. (2011)	3,0	57	1	98, 2%
Galindo-Moreno et al. (2012)	3,0	97	4	95,9%
Oyama et al. (2012)	3,0	17	0	100%
King et al. (2016)	3,0	62	2	96,8%
Total		405	12	97%

Table IV- Survival rate estimated by regions.

Location	Authors	Nº of implants	Nº of fails	Survival Rate
Maxilla/Mandible	Zembic et al. (2011) Sohn et al. (2011) King et al. (2016) Vigolo et al. (2004) Oyama et al. (2012)	248	8	96,8%
Maxilla	Degidi et al. (2009) Galindo-Moreno et al. (2012)	157	4	97,5%

Table V - Survival rate estimated by time of restoration

Restoration time	Authors	Nº of implants	Nº of fails	Survival Rate
Immediate	Zembic et al. (2011) Sohn et al. (2011) Degidi et al. (2009)	105	1	99,0%
Delayed	King et al. (2016) Oyama et al. (2012) Galindo - Moreno et al. (2012) Degidi et al. (2009) Vigolo et al. (2004)	300	11	96,3%

The study of Degidi et al (2009) placed 60 implants, 30 with immediate load and 30 with delayed load.

Table VI– Reasons of implant's failure

Authors	Failures	Comercial Trademark	Follow up period (years)	Location of the implants	Failures location	Reasons
King et al. (2016)	2	OsseoSpeed TX	3	Lower incisors and upper lateral incisors	Not described	The implants were lost before loading. One was removed due to insufficient healing and the other due to infection.
Zembic et al. (2011)	1	Nobel Biocare	1	Lower incisors and upper lateral incisors	Lower incisor	The authors did not mentioned the reasons of the failure.
Sohn et al (2011)	0	Biohorizons	±2	Lower incisors and upper lateral incisors	Not described	100% survival rate
Degidi et al. (2009)	0	It was not mentioned	3	Upper lateral incisors	Not described	100% survival rate
Vigolo et al. (2004)	5	3i/Implant Innovations	7	Upper lateral incisors	Two implants were lost in the first premolar region in the second surgery, 2 implants in the lower incisor in the second surgery and 1 implant in the superior lateral incisor (one month after cementation of the provisional).	The failures were related to poor bone quality at the recipient site and to occlusal problems.
Galindo- Moreno et al. (2012)	4	Astra Tech	1	Upper lateral incisors	Upper lateral incisors	Three implants were lost due to insufficient healing and one implant was lost due to infection.
Oyama et al. (2012)	0	Xive S	1	Lower incisors and upper lateral incisors	Not described	100% survival rate
Total	12					

Table VII - Articles included in this study

	Authors	Title	Year	Restoration Delivery	Design Study	Diameter (mm)	Length (mm)	Surface characteristics
2	Paul King, Carlo Maiorana, Ralph G. Luthardt, Katarina Sondell, Jesper Øland, Pablo Galindo-Moreno, Peter Nilsson	Clinical and Radiographic Evaluation of a Small-Diameter Dental Implant Used for the Restoration of Patients with Permanent Tooth Agenesis (Hypodontia) in the Maxillary Lateral Incisor and Mandibular Incisor Regions: A 36-Month Follow-Up	2016	6-10 weeks	prospective	Ø 3,0	11 to 13 to 15	Titanium (Ti)
24	A. Zembić, L. H. Johannesen,S. Schou,,P. Malo,T. Reichert,M. Farella,C. H. F. Ha¨mmerle	Immediately restored one-piece single- tooth implants with reduced diameter: one-year results of a multi-center study	2011	Provisional immediate and definitive from 1,9 to 14,5 months	prospective	Ø 3,0	13 - 15	surface is oxidized
26	Dong-Seok Sohn, DDS, PhD1/ Min-Su Bae, DDS2/Jeong-Uk Heo, DDS, PhD3/ Jun-Sub Park, DDS, PhD3/Sun-Hae Yea, DDS4/Georgios E. Romanos, DDS, PhD, Prof Dr Med Dent5	Retrospective Multicenter Analysis of Immediate Provisionalization Using One-Piece Narrow-Diameter (3.0-mm) Implants	2011	Provisional immediate and definitive = 3 months in the mandible and 5 months in maxilla	retrospective	Ø 3,0	12 e 15	NR
27	Marco Degidi,* Diego Nardi,* and Adriano Piattelli†	Immediate Versus One-Stage Restoration of Small-Diameter Implants for a Single Missing Maxillary Lateral Incisor: A 3-Year Randomized Clinical Trial	2009	Immediate load = 30 implants Delayed load = 30 implants after 6 months	Prospective	Ø 3,0	13 e 15	grit-blasted and acid-etched

36	Paolo Vigolo, Dr Odont, MScD1/Andrea Givani, MD, DDS2/Zeina Majzoub, DCD, DMD, MScD3/ Giampiero Cordioli, MD, DDS4	Clinical Evaluation of Small-Diameter Implants in Single-Tooth and Multiple-Implant Restorations: A 7-year Retrospective Study	2004	3 - 6 months	retrospective	Ø 2,9 Ø 3.,25	Ø 2,9mm = 8,5-10-13 e 15 Ø 3,25= 8,5-10-11.,-13 e 15	NR
47	Pablo Galindo-Moreno, Peter Nilsson, Paul King, Jonas Becktor, Stefano Speroni Alexander Schramm, Carlo Maiorana	Clinical and radiographic evaluation of early loaded narrow diameter implants – 1-year follow-up	2012	6–10 weeks	prospective	Ø 3,0	11 - 13 e 15	NR
52	Kotaro Oyama, DDS, MS1/Joseph Y. K. Kan, DDS, MS2/ Kitichai Rungcharassaeng, DDS, MS3/Jaime Lozada, DDS4	Immediate Provisionalization of 3.0-mm- diameter Implants Replacing Single Missing Maxillary and mandibular Incisors: 1-Year Prospective Study	2012	After 3 months	prospective	Ø 3,0	least 11	threaded grit-blasted thermal acid-etched implant

	Location	Commercial trademark	Restoration Type	Type of fixed abutments	Follow up (Year)	Total number of patients	Nº of implants	Failures	Survival Rate
2	Lower incisors and maxillary lateral incisors.	OsseoSpeed TX	Single prosthesis	Trans mucous Titanium abutments TiDesign (Dentsply)	3	38	62	2	96,80%
24	Lower incisors and maxillary lateral incisors	Nobel Biocare	Single cemented prosthesis	Implant's abutment	1	47	57	1	98,2%
26	Lower incisors, maxillary lateral incisors, and narrow labiolingual width in the mandibular incisor areas.	Maximus 3,0, Biohorizons	Single and partial fixed prosthesis.	Prepared abutment	2,9	36	62 – 18 single restoration	0	100%
27	Lateral maxillary incisor	NR	Single prosthesis	Abutments TempBase, dentsply Friadent	3	60	60	0	100%
36	Maxilla and mandibles	3i/ Implant Innovations, Palm Beach Gardens, FL	Single and partial	UCLA with gold base	7	165	192 Ø 2,9= 100 Ø 3,25= 92 94 single restorations	Total of failures:9 For single restoration: 1 failure	Total: 95,3%. For single restorations: 98,9%
47	Superior and inferior lateral incisors	(OsseoSpeed™ TX 3.0S) Astra Tech	Single prosthesis	TiDesignTM abutment	1	69	97	4	95,9%

52	Maxillary lateral incisor, mandibular incisor lateral and central	(Xive S, Dentsply)	Single crowns	Prefabricated abutment (Friadent EstheticBase Abutment, Dentsply)	1	13	17 maxillary lateral incisor=(9) mandibular incisor lateral and central =(8)	0	100%

CAPÍTULO 2 – ARTIGO 2

Reis TA, Zancopé K, Morais LL, Miguel VB, Castro CG, Neves FD. Mechanical behavior of narrow dental implants. Wulfenia. 2018 Set 25(9):23-33.

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Acceptance Letter

Date: Sep 2018 **Ref: pumJyUi**

Dear Author(s),
TaÃ-s Alves dos Reis, Karla ZancopÃ©, Lyzandra Lima M orais, Vanessa Borges Miguel, Carolina GuimarÃ£es Castro, FlÃ¡vio Domingues das Neves

We are pleased to inform you that based upon the editorial decision and the three reviewers' comments, your paper entitled '**Mechanical behavior of narrow dental implants**' has been accepted for publication in **Volume. 25, Issue. 9** of '**Wulfenia**' Journal.
Thank you for contributing to our journal. If you have any query, please do not hesitate to contact us.

Professor Dr. Vienna S. Franz
Editor-in-Chief
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Abstract
The objective of the present study was to evaluate the mechanical behavior of two different Morse taper implant systems. Twenty self-locking Morse taper implants, 2.9 mm in diameter (FAC), and 20 Morse taper implants, 3.5 mm in diameter (CM) were divided into two groups (n=10), submitted to strength to failure test, optical microscopic evaluation of fracture, metallographic analysis of the alloy, finite element analysis and strain gauge test. The statistical analysis was performed using the Student's t-test (α=0.05). The resistance to fracture was statistically different ($p<0.001$) between FAC (225.0±19.8 N) and CM (397.3±12.5 N). The optical microscopic evaluation showed that implants became fractured in the discontinuity region of the abutment/implant interface, the region of stress accumulation in FEA. Metallographic analysis showed that implants from the FAC group are composed of titanium-aluminum-vanadium alloy. In the strain gauge test, there was no statistical difference (p=0.833) between CM (1064.8±575.04 μS) and FAC (1002.2±657.6 μS). Due to a lack of clinical data with respect to the use of these implants, it is recommended that they be used in areas with low masticatory effort.

Keywords: implantology, fracture resistance, strain gauge.

1. Introduction

In recent decades, the use of dental implants has progressively improved the planning and management of patients who have partially or completely lost their teeth (Anitua et al, 2010). For successful rehabilitation, the appropriate selection of the implant type is crucial. The diameter is one factor that should be considered: some specific conditions restrict the placement of a regular implant, such as a severely resorbed and narrow ridge, a narrow mesiodistal space and replacement of teeth with small cervical diameters, such as inferior incisors (From et al, 2007; Davarpanah et al, 2000). Chronic pathological conditions, including endodontic and periodontal problems could also result in severe bone defects, resulting in narrow alveolar ridges in areas of anterior teeth (Park et al, 2010; Araujo et al, 2005; Fiorellini et al, 2005).

Due to these limitations, small diameter implants (less than 3.75 mm) were introduced in Implantology and designed for narrow interdental spaces (spaces not compatible with implants with a diameter of 3.75 mm or more) (Comfort et al, 2005; Andersen et al, 2001). However, these narrow implants were still not able to solve some cases with narrower spaces. Therefore, several companies presented implants with diameters of 3.0 mm or less, to solve border situations. Moreover, the prosthetic connection also developed alongside the rise of internal connections, such as the inner hexagon and Morse taper, since it is considered an important factor that promotes interference in stress distribution (Zancopé et al, 2017). Beyond this, the development of alloys with higher strength was important for the manufacturing of narrow implants, as it can be observed in the titanium Ti6Al4V alloy. This alloy consists in a more compact and resistant alloy and because of this could present higher strength and a better maintenance on the osseous apposition, especially on treated surfaces (sandblasted or acid-etched

titanium surface, for example) (Hyzy et al, 2016). Some studies showed that this alloy combined with theses treated surfaces can enhanced osteoblast differentiation, production of local factors in vitro and improved the osseointegration process in vivo (Olivares-Navarrete et al, 2014). Besides, hydrophilic surface maintained in an isotonic solution of 0,9% sodium chloride accelerates the bone area apposition and bone-to-implant contact interface around the implants during early stages of bone formation, providing highest degree of osseointegration (Sartoretto et al, 2017).

Neodent launched in the market in 2013, a narrow implant with 2.9 mm diameter[1], which was developed for cases where the edentulous area has small spaces (regions of maxillary lateral incisor and mandibular incisors). Its main attraction is that it has a self-locking Morse taper interface, with no internal screw, in order to preserve its strength to avoid the narrowing of the walls.

Therefore, the aim of this study was to evaluate the mechanical behavior of two different Morse taper systems of narrow dental implants (self-looking Morse taper implants, 2.9 mm in diameter, with 5° angulation of the internal conical portion – FAC; and Morse taper implants, 3.5 mm in diameter, with 11.5° angulation of the internal conical portion – CM[2]). The null hypothesis is that there is no difference in resistance to fracture and deformation of the external walls of these two Morse taper implants.

2. Material and methods

Two different Morse taper implant systems were evaluated in the current study: CM implants with 3.5mm diameter[2] and implants with 2.9mm diameter[1]. CM implants are Morse taper implants with 11.5° angulation of the internal conical portion, and in the present study, are 3.5 mm in diameter. The narrow implants (FAC) are Morse taper self-locking implants with 5° angulation of the internal conical portion and are 2.9 mm in diameter (Figures 1 and 2 respectively).

In total, 20 CM and 20 FAC implants were evaluated regarding their mechanical strength and deformation, by two methodologies: the strength to failure test (n=10) and the strain gauge test (n=10) (Table 1).

2.1. Strength to failure test.

Each implant was positioned in a metallic holder (Zancopé et al, 2017). The implant shoulder was also positioned 4 mm above the metallic holder, to simulate critical marginal bone crest resorption. A metallic index 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 the manufacturer's recommendation.

The samples were subjected to a 90° compressive load at a crosshead speed of 0.5 mm/min in a mechanical testing machine[3] using a stainless-steel spherical point (4 mm diameter) connected to a load cell of 500 KN capacity (Carneiro et al, 2016).

A computer mounted in association with the machine was programmed to interrupt the test cycle process when one of the following occurred: a fracture, an abrupt break in resistance, or a displacement greater than 5.0 mm. A load was applied at 2 mm of the abutment platform (Figure 3).

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) and convert it into graphics.

The samples were numbered from 1 to 10 in each group and a table was produced according to the force applied (N) versus the displacement of the implant (mm).

After the test, the implant and the abutment were removed from the metallic holder, each sample was identified, and a macroscopic evaluation was performed to verify the compression mark of the screw in the implant's body to confirm that there was no sample displacement during the test. This macroscopic analysis demonstrated that the screw of the metallic holder avoided the displacement of the samples during the strength to failure test.

2.2. Optical Microscopic Evaluation.

Three samples were examined. The microscopic evaluation was performed to identify the different forms of fractures that occurred for both implant systems during the strength to failure test. For the analysis, the surface of the fracture was examined for each sample using an optical microscope[4] with magnifications of 50x and 200x.

2.3. Metallographic Analysis.

The metallographic analysis was performed to determine the microstructure of the implant's alloy. For this analysis, the alloy was examined using an optical microscope with a magnification of 200x.[5] Prior to the analysis, the samples were submitted to acid treatment in order to increase the visualization of the metallic characteristics.

2.4. Finite Element Analysis.

Two three-dimensional finite element models were created, representing each experimental group. The drawings of all parts of models (implant, abutment, and abutment screw) were supplied by the manufacturer (Neodent) in *.IGES format. The stress analysis was performed using FEMAP with NX Nastran (v11.1.1 64-bits).[6]

All models were considered homogeneous, isotropic, and linearly elastic. The material properties are described in Table 2. To create the mesh, a semiautomatic meshing tool was used, with tetrahedral solid elements with quadratic trial function (element type SOLID187).

The boundary conditions were determined with sliding contact with friction between the abutment and implant. The bottom nodes of the implant were held fixed to avoid movement of the model.

The load (50 N) was applied as described in the strength to failure test section, to simulate the same conditions for analysis of the stress distribution on the implant.

2.5. Strain Gauge Test.

Ten Morse taper implants, 2.9 mm in diameter, with 5° angulation of the internal conical portion (FAC) and 10 Morse taper implants, 3.5 mm in diameter, with 11.5° angulation of the internal conical portion (CM) were manufactured specifically for this test without external threads, in order to allow strain gauge[7] fixation. All implants were mounted in resin, in order to expose 3 mm of the cervical portion. Then, the abutment was fixed to the implant as recommended by the manufacturer (Figure 4) (Castro et al, 2015).

One strain gauge was fixed with cyanoacrylate glue[8] to the cervical portion of the implant to measure the cervical deformation during the loading application. The strain gauge was connected to a data acquisition device.[9] After switching the acquisition device on, the value of the gauge factor was recorded. The samples were subjected to a 45°

oblique compressive load, from 0 to 200 N, at a crosshead speed of 0.5 mm/min in a mechanical testing machine.[3]

At the end of the tests, the strain gauge was completely disconnected from the acquisition device, which was switched off. The same operator performed all the tests in the same experimental session in order to prevent the yields from being altered by environmental conditions.

2.6. Statistical Analysis.

The statistical analysis of the strength to failure test and strain gauge tests were performed using the Student's t-test (α=0.05). A statistical software (Sigma Plot version 12.0; Systat Software Inc.) was used to perform all analyses.

3. Results

The mean and standard deviation of the strength to failure test (N) are show in Table 3. There was a significant difference ($P<0.001$) between the FAC and CM groups. Therefore, the mechanical performance of the FAC group implant compared to the CM group was different according to strength to failure test.

The optical microscopic evaluation demonstrated that all implants fractured, and the fractures tended to occur in the discontinuity region of the abutment/implant interface (Figures 5 and 6).

The metallographic analyses verified the microstructure of the titanium alloy and demonstrated that the CM implants contained titanium grade IV (commercially pure). In contrast, the FAC group implants contained a Ti6Al4V alloy (Figure 7).

The finite element analysis revealed that the region with the highest stress concentration was the area with no contact between the abutment and implant (Figures 8 and 9). This trend was confirmed by microscopic analysis demonstrating that fractures occurred at this region.

For the strain gauge analysis, there was no statistical difference between FAC and CM groups ($P=0.833$; Table 4).

4. Discussion

The null hypothesis of this study was rejected. Although the strength to failure test demonstrated that the mechanical performance of the FAC group was inferior to the CM group ($P<0.001$), for the strain gauge analysis, there was no statistical difference between the analyzed groups ($P=0.833$).

Narrow implants are used to rehabilitate narrow edentulous spaces. Even with the majority of cases being solved with implants 3.25 mm to 3.5 mm in diameter, there remains an issue for rehabilitating more narrow spaces. In order to obtain an acceptable degree of mechanical performance for 2.9 mm narrow implants, two solutions were found by manufacturers: a self-locking connection, avoiding the necessity of internal threads, and stronger raw material. As presented in Table 2, the tensile strength for Ti6Al4V is 9% higher than titanium grade IV. Even so, the mechanical behavior in the strength to failure test of the 2.9 mm implant was inferior to the 3.5 mm implant, emphasizing that it is necessary to follow manufacture's recommendations. Some studies have already show that Ti6Al4V alloy presents good strength and a better maintenance on the osseous apposition, especially on treated surfaces (sandblasted or acid-etched titanium surface, for example) (Hyzy et al, 2016; Olivares-Navarrete et al, 2014). However, its

inappropriate use could favor fractures, as well as not accomplishing frequent occlusal adjustments.

The FEA and microscopic examination revealed that the fractures occurred more frequently in the region where there was no contact between the abutment and the implant (Figures 8 and 9). The region with the highest stress concentration is the most fragile and susceptible to fracture, and could be observed in the discontinuity of the interface abutment/implant. Nevertheless, a critical situation was simulated. In clinical conditions, it is expected that bone preserves this region, and the implant receives stress at approximately 45° along the long axis. This situation is similar to the strain gauge analysis, in which there was no statistical difference between the groups, demonstrating that the differences between the evaluated systems did not affect the deformation around the external walls of the cervical region. This experimental finding confirms that FAC implants could be used in areas without great masticatory effort.

In a comparative laboratory study (Alum et al, 2008) on the mechanical performance of a series of narrow implants, it was concluded that implants with diameters smaller than 3 mm were significantly inferior compared to implants of the control group (Straumman 4.1 mm RN). The fracture test demonstrated that the maximum load for the Straumman implants were 989 N (±107 N) for the 4.1 mm RN implant, and 619 N (±50 N) for the 3.3 mm RN implant (an implant known to have a risk of fracture in clinical use). Due to little data available for implants smaller than 3 mm, caution is recommended to professionals when they consider their use. The results of this study confirm this statement. Therefore, the FAC group implants have clinical indications restricted to upper lateral incisors, lower incisors and to support overdentures. These implants are not recommended in regions of high masticatory effort.

With respect to performance and clinical longevity of implants smaller than 3 mm, a systematic review (Klein et al, 2014) related a survival rate upwards of 90%, with a follow-up between 1 and 3 years. In a recent retrospective study (Anitua et al, 2016), it was analyzed narrow splinting implants (2.5 mm diameter) compared to standard implants in their effectiveness in supporting fixed partial and total dentures. Thirty-seven implants, 2.5 mm in diameter, were fixed in maxillae and mandibles in 20 patients with a mean age of 54 years at the time of surgery. The results demonstrated a great survival rate in the long term: 97.3% for implants and 92.0% for prostheses. The implants' mean follow-up time since insertion was 6.5 ± 3.2 years. However, these results could be due to the implant splitting to a fixed partial denture. This design may minimize the probability of failure in implants and prostheses.

The benefit of using narrow implants is that specific cases can be treated, for example, the replacement of teeth with small cervical diameters (e.g. incisors) (Froum et al, 2007; Davarpanah et al, 2000), reduction or avoidance of bone grafts (Zinsli et al, 2004; Davarpanah et al, 2000; Barber et al, 1994) or preliminary orthodontic treatment (Barber et al, 1994). This could help some patients, especially elderly patients or patients with risk factors (such as chronic diseases) that can benefit from the use of narrow implants with reduced surgical invasion (Klein et al, 2014). Epidemiological studies show that edentulous patients, especially elderly ones, are not able or disposed to be submitted to invasive surgical procedures (Carlsson et al, 2010; Narby et al, 2008). Furthermore, there are some concerns and restrictions against longer treatments, associated with pain and complications (Ellis et al, 2011; Walton et al, 2005). However, a narrow implant (with a diameter inferior to 3.0 mm) that can be used in any clinical situation still does

not exist. Therefore, material development should be pursued to achieve an implant as resistant as FAC group implants, but without the limitations observed in this study.

5. Conclusion

Within the limitations of this study, it could be concluded that the FAC group implants has inferior mechanical strength when compared to CM implants that are 3.5 mm in diameter. Nevertheless, the deformation around the external walls showed no statistical difference. In addition to a lack of clinical data with respect to the use of these implants, it is recommended that they be used in areas with low masticatory effort.

Acknowledgements

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Footnotes

[1] Facility, Neodent, Curitiba, PR, Brazil
[2] Alvim, Neodent, Curitiba, PR, Brazil
[3] EMIC DL 2000, Sao José dos Pinhais, Brazil
[4] AxioVision Imager. A1m; Zeiss, Oberkochen, Germany
[5] AxioVision Imager. A1m; Zeiss, Oberkochen, Germany
[6] Siemens, Berlin, Germany
[7] Excel sensors, São Paulo, Brazil
[8] Super Bonder Loctite, Rocky Hill, USA
[9] ADS0500IP Lynx, São Paulo, Brazil

Tables

Table 1. Type of implants and abutments in each test.

Type of test	Implant	Abutment
Resistance to fracture test	Morse taper self-locking implants with 5° angulation of internal conical portion (2.9 mm in diameter) – FAC	Facility anatomic abutment (1.5 mm)
	Morse taper implants with 11.5° angulation of internal conical portion (3.5 mm in diameter) – CM	Universal abutment
Strain gauge test	Morse taper self-locking implants with 5° angulation of internal conical portion (2.9 mm in diameter) – FAC	Facility anatomic abutment (1.5 mm)
	Morse taper implants with 11.5° angulation of internal conical portion (3.5 mm in diameter) – CM	CM exact lateral anatomic abutment (1.5 mm)

Table 2. Property of the materials.

Structure	Young's Modulus (Mpa)	Poisson's Ratio (V)	Yeld Stress Ratio (Mpa)	Tensile Strength (MPa)
Titanium grade IV	103000	0.361	703	970.1
Ti6Al-4V-ELI titanium alloy	105000	0.361	881	1059.4

Table 3. Mean and standard deviation of the strength to failure test.

Groups	CM	FAC
Data	397.3±12.5 N^{A}	225.0±19.8 N^{B}

Values with different superscript letters were significantly different in row, based on student t-test.

Table 4. Mean and standard deviation of the strain gauge test.

Groups	CM	FAC
Data	1064.8 ±575.04 μS^{A}	1002.2±657.6 μS^{A}

Values with same superscript letters were not significantly different in row, based on student t-test.

Figures

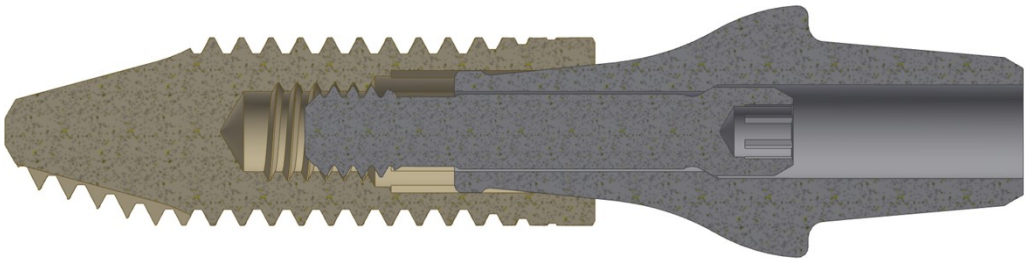

Figure 1 – CM implants - Morse taper implants with 11.5° angulation of the internal conical portion and 3.5mm in diameter.

Figure 2 – FAC group implants (FAC) - Morse taper self-locking implants with 5° angulation of the internal conical portion and 2.9 mm in diameter.

Figure 3 – The implant and the metallic holder were fixed on the mechanical testing machine (EMIC; 2000DL) and submitted to a load cell of 500 KN capacity (KN500; EMIC).

Figure 4 – Strain gauge fixed in the cervical portion of the implant. Note that the implant was fabricated without external threads to permit this fixation.

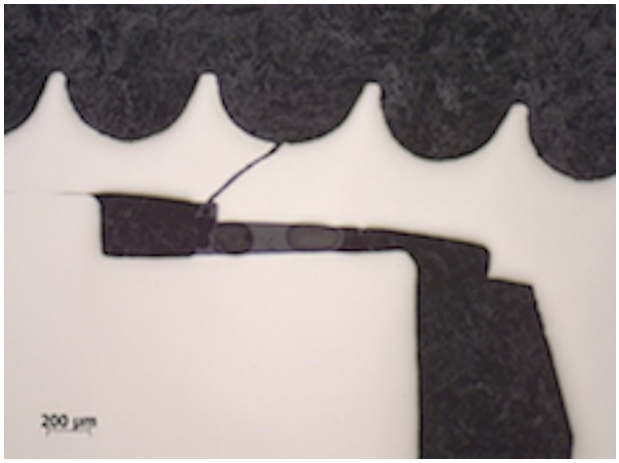

Figure 5 – Optical microscopic evaluation: implant fracture at the discontinuity region of the abutment/implant interface (approximated view). - FAC group.

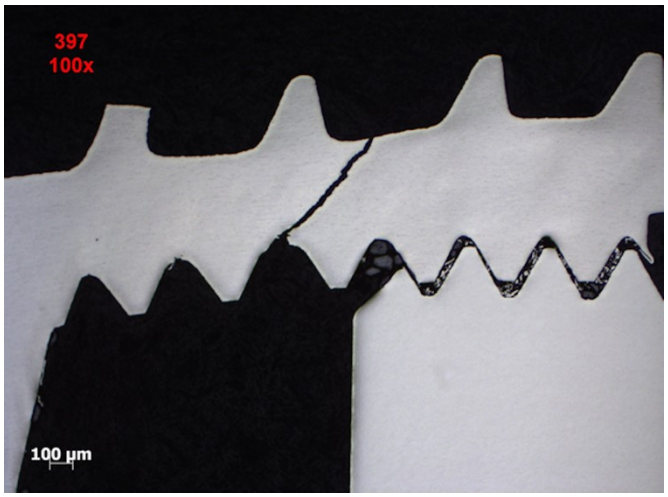

Figure 6 – Optical microscopic evaluation: implant fracture at the discontinuity region of the abutment/implant interface (approximated view). – CM group.

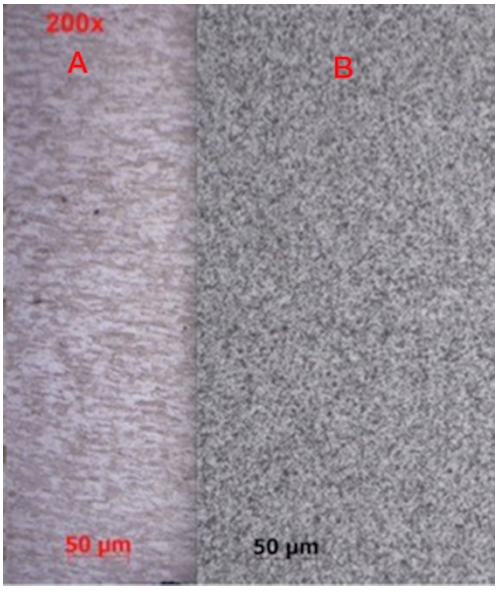

Figure 7 – Metallographic analysis of the CM group (A) and FAC group (B).

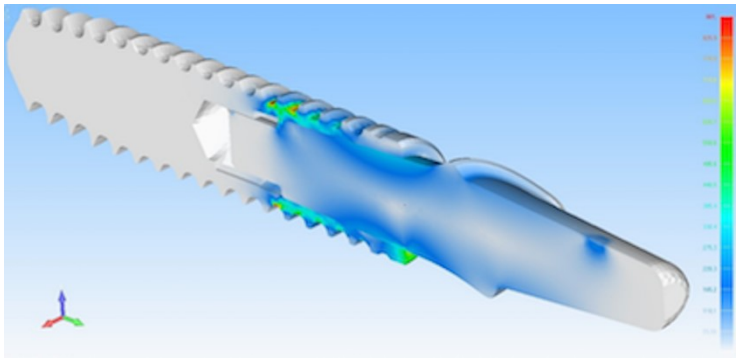
Figure 8 - Finite element analysis of the FAC group implants: stress accumulation is represented in the red color located in the region with no contact of abutment/implant.

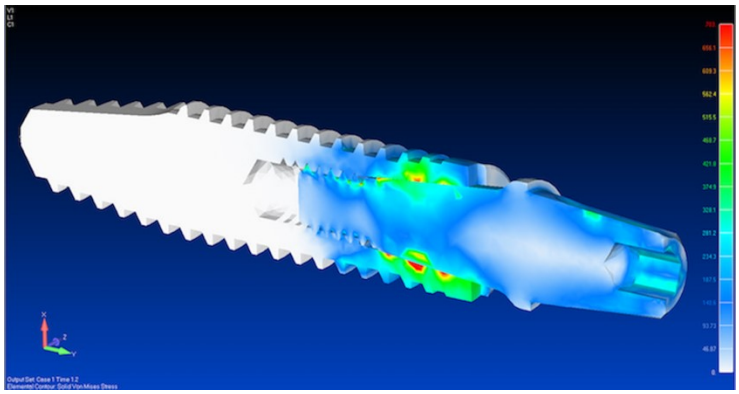
Figure 9- Finite element analysis of the CM group: stress accumulation is represented in the red color located in the region with no contact of abutment/implant.

CAPÍTULO 3 – ARTIGO 3

Reis TA, Zancopé K, Karam FK, Neves FD. The biomechanical behavior of extra-narrow implants after fatigue and pull-out tests. J. Prosthet Dent. Artigo em revisão.

Biomechanical behavior of extra-narrow implants after fatigue and pull-out tests

ABSTRACT

Statement of problem. Narrow implants have restricted indications that may lead to failures such as the fracture of the implant when these indications are not followed.

Objective. To investigate the mechanical behavior using the fatigue limit test of the 2.9 mm diameter implant and to investigate the Morse effect of 2 different Morse taper systems, namely: 2.9 mm diameter (FAC group) and 3.75 mm diameter (CM group), using pull-out test. The null hypothesis is that the tensile strengths of the components for both groups are similar.

Materials and methods. Fatigue properties were determined on 13 specimens under 6 loads. The test was performed with 15 Hz and 5×10^6 cycles. In the pull-out test, the components were divided into 2 groups (n=8), namely: the FAC group (2.9 mm diameter) and the CM group (3.75 mm diameter). The pull-out test statistical analysis was performed with the Student t-test (α=.05).

Results. Thirteen specimens underwent the fatigue test. Only 5 did not fail at the frequency and number of cycles examined. Three of the samples did not fail with a load of 130 N. The pull-out test yielded a significant difference between the FAC and CM groups ($P < .001$).

Conclusion. According to the fatigue test, the extra-narrow implant (Facility; Neodent) was compatible with low masticatory effort regions, as indicated by the manufacturer. The best performance of the FAC group in the pull-out test may be due to its design that

uses the Morse effect to anchor its intermediates, as well as to its internal conical portion angulation.

CLINICAL IMPLICATIONS

Although manufacturers recommend narrow implants exclusively for regions of low masticatory effort, many studies still report the use of these implants in posterior regions, which may lead to the fracture of these implants over a long follow-up period. Therefore, the use of these implants should be recommended judiciously. The unique Morse interface without internal screws may be favorable for the best result observed in the pull-out test when compared to the 3.75 mm diameter implants. This interface prevents the narrowing of the walls with the placement of internal threads, which may be one of the possible factors that gives rise to the clinically acceptable mechanical resistance of this implant.

INTRODUCTION

The planning for patients who lost dental elements has become more predictable through the use of osseointegrated implants because it is possible to rehabilitate from single losses to fully edentulous arches.[1,2] With the modifications in the designs and surfaces of the implants, it was possible to adapt them to different locations and to varied bone patterns where they should be placed.[3]

The quantity and quality of the remaining bone are critical when determining whether it is possible to place regular diameter implants, which are defined as the 3.75 mm diameter implant. However, in cases where the alveolar ridge has a reduced lingual vestibule size (fewer than 4 mm wide), the use of regular diameter implants becomes impractical due to the increased risk of implant exposure.[4] Likewise, when a regular-diameter implant is placed in a reduced space between the roots of the teeth, the risk of periodontal ligament damage of adjacent teeth is increased.

Some techniques allow for the increase of bone volume through grafts or osteogenic distraction.[5] However, these procedures add both risks and costs to patients, such as unpredictable bone resorptions, membrane exposure risk and prolonged treatment time. Moreover, these procedures may cause some patients to withdraw from treatment.[6] Therefore, narrow-diameter implants are an exceptional treatment option in regions with limited width such as the rehabilitation of adjacent teeth with small mesio-distal space (mandibular incisors and lateral maxillary incisors) and severely reabsorbed ridges.[7] All implants with the diameter fewer than 3.5 mm are considered narrow implants.

Many studies have reported the use of narrow implants to address border clinical situations using a variety of surgical techniques (immediate loading, with or without allografts, or through guided surgery).[3,4,8-10] Both medium and long-term survival rates were satisfactory (from 96.9% to 100%), with a follow-up period varying from 1 to 7 years.[11,12] However, their indication is restricted to regions of low masticatory effort (mandibular incisors and lateral maxillary incisors) and fractures may occur when the implants are not placed in accordance with the manufacturer's recommendation.[13-15] Perhaps, the next step should be the development of more resistant alloys that could allow for further indications.[16]

Some narrow implants have been developed without the internal threads to permit a decrease in the diameter with an acceptable mechanical behavior in low masticatory effort regions. Facility (Neodent) is a narrow implant with a diameter of 2.9 mm and 5 degrees of angulation of the internal conical portion. Its most appealing feature is that it has a Morse taper frictional lock connection with no internal screw in order to preserve its strength and the narrowing of the walls.

The aim of the present study was to investigate the mechanical behavior through fatigue limit of the 2.9 mm diameter implant (Facility; Neodent) under fatigue loading (dynamic test) in compliance with ISO 14801:2007. The authors also attempted to investigate the Morse effect of two different Morse taper systems: 2.9 mm diameter implants (Facility; Neodent) with 5 degrees of angulation of the internal conical portion (FAC group) and 3.75 mm diameter Morse taper implants (Titamax CM; Neodent) with 11.5 degrees of angulation of the internal conical portion (CM group) through the pull-out test.[17] The null hypothesis is that the tensile strengths of the components for the 2 groups of implants described above are similar.

MATERIAL AND METHODS

The fatigue loading test was performed in compliance with ISO 14801:2007. The free end of the component was covered with a semispherical rigid body the center of which coincided with the center of the free longitudinal axis and was anchored at 11.0 ±0.5 mm (measured on a line parallel to the longitudinal axis of the implant). For the fatigue loading test, a mechanical test cone component was developed for the extra-narrow implant (Facility Ø 2.9 mm x 12 mm; Neodent) in order to transfer the load through the semispherical free edge. A schematic illustration of the fatigue test is presented in Figure 1.

The loading force was applied to the semispherical surface by means of a device with a flat surface perpendicular to the load direction. The device was not restricted in the transverse direction of loading so as not to reduce the magnitude of the generated bending moment. This was done by using a junction transducer placed at least 50 mm from the semispherical surface. In the fatigue test, the implant was placed 3.0 mm above the bone level (simulating a high bone resorption) in a rigid base for anchorage angled at 30 degrees.

Fatigue test

The implant components for mechanical test (Facility; Neodent) were assembled and submitted to axial pressure as recommended by the manufacturer. First, a static loading test was performed in a wear simulator (Instron 3382; Instron; with 100 KN capacity) with the same configuration as that used for the dynamic loading test (performed in a wear simulator Instron E3000; Instron with 3 KN capacity). The static

loading test was performed to obtain the maximum load and 3 specimens were used (speed of 1.0 mm/min).

In the dynamic loading test, fatigue properties were determined through multiple tests on 13 specimens (2.9mm diameter implant; Facility Ø 2.9 mm x 12 mm), under 6 loads (194 N, 178 N, 162 N, 155 N, 150 N, and 130 N), which were selected from the maximum load, obtained from the static loading test. The test was performed with a loading frequency of 15 Hz and 5×10^6 cycles. This number of cycles corresponds to an estimated 5-year clinical function. The fatigue limit was defined as the load limit value below which the test object could withstand more than 5×10^6 of regular cycles without failure. These loading values do not correlate with the clinically presented values. Rather, they were obtained by testing in compliance with ISO 14801:2007, item 5.6.2.

Pull-out test

The test was performed to evaluate the tensile strength of Morse taper implants and abutments (anatomic abutment of 1.5 mm) of different groups of internal Morse taper designs. The components were divided into 2 groups (n=8) according to their internal Morse taper design, namely, the FAC group (2.9 mm diameter), with Morse taper frictional lock connection with 5 degrees of angulation of the internal conical portion and the CM group (3.75 mm diameter), with Morse taper implants with 11.5 degrees of angulation of the internal conical portion. To perform the tests, the implants were placed in a plastic support.

All of the abutments (anatomic abutment of 1.5 mm) were placed in their respective implants. The company-developed pneumatic hammer was used to place the extra-narrow abutment (Facility; Neodent). According to the manufacturer's

recommendation, these abutments should be beaten 3 times with a hammer for optimal installation. Both groups had their abutments placed in this fashion with no screwing so that the screws of the CM abutments were removed.

The set implants/abutments were placed in a mechanical machine (Multitest 2.5 XT; Mecmesin). The measurement of the tensile force (kgf) required for the removal of the abutments was performed with a velocity of 5 mm/min and the obtained data were analyzed by software (Mecmesin) (Figure 2).

The statistical analysis of the pull-out test was performed with the Student t-test (α=.05). To perform all of the analyses, statistical software (Sigma Plot version 12.0; Systat Software Inc.) was used.

RESULTS

In the compression test, three specimens were used and the mean value obtained for the maximum load supported by the 2.9 mm-diameter implant (Facility; Neodent) was 324.34 N ±7.45. The results of the fatigue loading test were presented in a Wöhler diagram (load × cycles) summarizing the number of the cycles that each specimen withstood for each load (Figure 3).

The calculated bending moments are displayed in Table 1. Thirteen specimens underwent the dynamic fatigue test, but only 5 did not fail with the frequency and number of cycles determined for this test. According to the obtained results, the fatigue limit of the extra-narrow implant (Facility, Ø 2.9 mm × 12 mm; Neodent) with prosthetic interface of the Morse taper was 130 N. Eight specimens exhibited the fracture of the implant body.

The data obtained for each group in the pull-out test are described in Table 2. The mean and standard deviation of the pull-out test are shown in Table 3. A significant difference between the FAC and CM groups (P< .001) is observed. The Morse effect was 7.5 times harder to break in the FAC Group.

DISCUSSION

In the present study, the maximum load supported by the 2.9 mm-diameter implant (Facility; Neodent) was 324.34 N ±7.45. In a study, that compared different 3.5 mm Morse taper implants, a similar value was found for the implants with no index for the implant and no index abutment (353.7 N ±51.9).[17] This static test was a prerequisite for obtaining the reference load for the extra-narrow implant (Facility; Neodent) fatigue test.

Fatigue properties were determined by testing 13 specimens under 6 different loads that were selected from the maximum load obtained from the static test with the same configuration as that of the dynamic test. The fatigue limit was defined as the load limit value below which the test object could withstand more than 5×10^6 of regular cycles without failure. For the extra-narrow implant (Facility; Neodent), the diameter does not vary and remains at 2.9 mm for all implant heights. The fatigue limit determined in the dynamic loading test was 130 N. This value is in accordance with the manufacturer´s recommendation for regions of low masticatory effort such as mandibular incisors and lateral maxillary incisors. It is important to point out that this implant was designed for specific clinical situations - low masticatory effort regions, in order to avoid invasive procedures for bone gain. In a study of fatigue testing, 36

specimens were divided into 2 groups according to diameter as follows: narrow (Ø 3.3 mm × 10 mm) and extra-narrow (Ø 2.9 mm × 10 mm).[15] The test was carried out under water at 9 Hz until failure or survival with 4 different loads (50 N, 100 N, 150 N, and 180 N) at 50.000 and 100.000 cycles. At the loads of 50 N and 100 N, the probability of survival was higher than 97% for both groups. When the load was increased to 150 N, the probability of survival after 100.000 cycles was 61.5% and 26% for Ø 2.9 mm and Ø 3.3 mm implants, respectively. At 180 N, for missions of 50.000 and 100.000 cycles, both implant diameters showed 0% reliability. These results agree with our findings. All of the failures observed in this study occurred with a load higher than 150 N, varying from 7.395 to 300.000 cycles. Even though manufacturers recommend narrow implants exclusively in regions of low masticatory effort, many studies still report the use of these implants in posterior regions. [4,13,14] This procedure may lead to the failure of these implants in the long follow-up period such as the fracture of the implant body.[13,14] When these implants are placed according to the manufacturer's recommendation, the survival rates are satisfactory, highlighting the importance of complying with instructions.[8,9,11,12]

According to ISO 14801:2007, the chosen loading frequency was 15 Hz and according to the literature, the human mastication frequency was found to be 1 to 4 Hz; therefore, the implants were submitted to the most unfavorable situation.[18] The number of cycles at each load was set at 10^6, thereby mimicking chewing and swallowing conditions over a 5-year period.[19]

Thirteen specimens underwent the dynamic fatigue test, but only 5 did not fail with the frequency and number of cycles determined for this test. One of them failed with 155.68 N maximum load, another with 150 N and other 3 with 130 N. That was the

load limit value, below which the test object could withstand a number greater than 5×10^6 of regular cycles without fail. Eight specimens exhibited the fracture of the implant body, indicating the overloading of the set when forces greater than those endured by the implant were employed (for example narrow implants placed in posterior region).

The null hypothesis for the pull-out test was rejected. The tensile strength of the FAC group components was higher than that for the components in the CM group. The pull-out test is one of the methods used to evaluate implant stability and the mechanical interface between the implant and the bone.[17] In addition, because pull-out tests are more efficient than insertion torque analysis, they are more commonly used to evaluate different designs in mini-implants.[17]

In this study, the authors chose this mechanical test to evaluate the stability given by the Morse effect in the Morse taper implants with different internal Morse taper designs. Although this is an unpublished evaluation in the literature, it is relevant, because the locations at which the forces applied on these implants are concentrated when their abutments are screwed on their respective platforms are already known, mainly through finite element analysis.[20] Prior to this study, the stability provided by the abutments lacking internal screws was still unknown when only the Morse effect was considered.

Implants with the diameter of 3.5 mm are considered narrow implants, but in some cases, even these implants may be too wide for the prosthetic space available. This was the main reason for the manufacturing of narrower implants. Regarding the differences between the groups tested in this study, the extra-narrow implant (Facility; Neodent) was developed with a unique Morse interface (with 5 degrees of angulation of

the internal conical portion which enhances the Morse effect) and without internal screws, which may have been favorable for the best result observed in the pull-out test compared to the CM group. Furthermore, this interface prevents the narrowing of the walls with the placement of internal threads which may be one of the possible factors giving rise to the clinically acceptable mechanical resistance of this implant. Therefore, it is clear that the extra-narrow implant has some specific technical and biomechanical characteristics and indications.

CONCLUSIONS

According to the results obtained from the fatigue test, extra-narrow implant (Facility; Neodent) with prosthetic frictional lock connection was compatible with low masticatory effort regions, in agreement with the manufacturer's recommendation. The best performance of the FAC group in the pull-out test may be due to its design without internal threads, with Morse effect to anchor its intermediates and the internal conical portion angulation of this implant. These data are clinically important because they emphasize the high values found for the traction of the extra-narrow abutments (Facility; Neodent) that are crucial for the stability of rehabilitations with this implant.

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TABLES

Table 1 – Bending moment calculated for each specimen (2,9mm diameter implants).

Specimen	Maximum load (N)	Minimum load (N)	Amplitude	Cycles	Point of failure
1	194.6	19.46	87.57	7.247	Implant thread near the anchorage base
2	194.6	19.46	87.57	7.395	Implant thread near the anchorage base
3	178.39	17.84	80.27	12.076	Implant thread near the anchorage base
4	178.39	17.84	80.27	11.4835	Implant thread near the anchorage base
5	162.17	16.22	72.98	300.000	Implant thread near the anchorage base
6	162.17	16.22	72.98	16.631	Implant thread near the anchorage base
7	155.68	15.57	70.06	104.715	Implant thread near the anchorage base
8	155.68	15.57	70.06	5.000.000	Without fail
9	150	15	67.50	185.314	Implant thread near the anchorage base
10	150	15	67.50	5.000.000	Without fail
11	130	13	58.50	5.000.000	Without fail
12	130	13	58.50	5.000.000	Without fail
13	130	13	58.50	5.000.000	Without fail

Table 2 – Results of pull-out test.

CM group	FAC group
39.6	193.4
29.3	277.1
25.6	368.9
33	267.1
27	231.5
27.4	227.8
42.6	253.4
49.6	231.9

Table 3 - Mean and standard deviation (SD) for FAC and CM groups in pull-out test.

Group	Mean	Standard deviation
FAC	256.3	52.4
CM	34.2	8.7

LEGENDS

Fig. 1 – Schematic drawing of fatigue test.

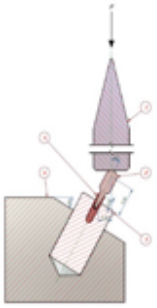
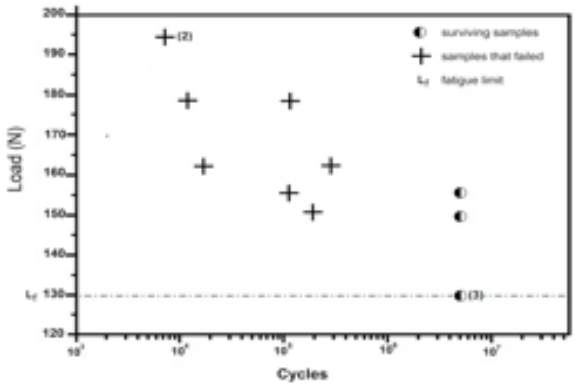


Fig. 2 – Set implant/abutments placed for pull-out test.

Fig. 3 - Wöhler diagram (load x cycles) for fatigue test with up to 5 x 10^6 cycles for thirteen specimens.



CAPÍTULO 4 – ARTIGO 4

Reis TA, Carneiro TAPN, Zancopé K, Neves FD. Reabilitação unitária com implante ultra- estreito: relato de caso clínico. Artigo redigido nas normas da revista Prosthesis Laboratory in Science (PLS).

Reabilitação unitária com implante ultra- estreito: relato de caso clínico.

Single rehabilitation with ultra-narrow implant: a case report

RESUMO:

Apesar das vantagens da instalação de implantes de diâmetro regular para reabilitações totais, parciais ou unitárias, em algumas situações seu uso está limitado. O implante Facility de 2.9mm de diâmetro é um implante com conexão protética Morse, sem parafusos internos. O presente trabalho tem como objetivo o relato de um caso clínico com a utilização do implante Facility. Paciente de 21 anos, gênero masculino, apresentava agenesia do elemento 32. No exame clínico podia ser observado espaço para a instalação de implante de diâmetro ultra –estreito. O tratamento proposto foi instalação de implante 2.9mm de diâmetro (Facility, Curitiba, Brasil) cuja indicação é compatível com o caso apresentado. A instalação do implante foi feita de acordo com a sequência de brocas sugerida pelo fabricante. Foi instalado o implante de 14mm de comprimento, posicionado 1.5mm infra ósseo com um cicatrizador de 2.5mm de altura. Uma prótese provisória adesiva direta foi instalada ao final do procedimento cirúrgico. Após o período de cicatrização de 6 meses foi instalado o munhão anatômico de 1.5mm altura e confeccionado provisório. Todas as etapas clínicas e laboratoriais foram feitas para a confecção da coroa metalocerâmica. Implantes estreitos apresentam boas taxas de sobrevida e sucesso quando instalados em áreas de pouco esforço mastigatório. Além do mais, estes implantes são excelentes opções para situações em que o espaço mésio-distal é reduzido, impedindo a instalação de implantes de diâmetro regular.

Descritores: Implantes dentários, desdentados, relato de caso.

ABSTRACT

Regular diameter implants present some advantages for total, partial or single rehabilitations. However, in some situations its use is limited. The Facility is an implant of 2.9mm diameter with Morse taper frictional lock connection with 5 degrees of angulation of the internal conical portion, without internal screws. The objective of this study was to report a clinical case using the Facility implant. A 21-year-old male patient presented agenesis of element 32. In the clinical examination, the space available was compatible for the installation of an ultra- narrow diameter implant. The proposed treatment was a 2.9mm diameter implant (Facility, Curitiba, Brazil), whose indication agrees with the presented case. The implant installation was done according to the drill sequence suggested by the manufacturer. The implant was 14mm long and was positioned 1.5mm below the bone crest with a healer of 2.5mm. A temporary direct adhesive prosthesis was made at the end of the surgical procedure. After the healing period of 6 months, it was installed the Facility anatomical abutment of 1.5mm height and provisional crown. All the clinical and laboratory stages were made for the preparation of the metal ceramic total crown. Narrow implants have good survival and success rates when installed in regions of low masticatory effort. Furthermore, these implants are excellent options for situations where the mesio-distal space is reduced, preventing the installation of standard diameter implants.

Descriptors: Dental implants, Xenarthra, case report.

Introdução

Quando existe a perda de elementos dentários, a preocupação em substituí-los vai além da estética. Devolver ao paciente função e qualidade de vida é o grande objetivo. Implantes mandibulares para reabilitações totais já demonstraram altas taxas de sucesso e desta forma se consolidava um dos princípios básicos desta reabilitação: a osseointegração.[1] A medida que as pesquisas avançavam, surgiam novas possibilidades para reabilitações com implantes, desde pacientes desdentados totais até pacientes com perdas unitárias.[34]

Apesar das vantagens da instalação de implantes de diâmetro regular para reabilitações totais, parciais ou unitárias, em algumas situações seu uso está limitado, especialmente quando existem áreas com pouco volume ósseo ou pequeno espaço mésio-distal entre elementos dentários. Esta limitação é resultado da remodelação óssea após da perda dentária, o que resulta em volumes ósseos insuficiente para a instalação de implantes de diâmetro regular,[26] seja em largura ou em altura.[4] Portanto, existem situações em que o implante de diâmetro regular (3,75mm de diâmetro) não pode ser utilizado, sendo recomendado alguns procedimentos cirúrgicos com o objetivo de conseguir volume ósseo adequado: distração osteogênica, reposicionamento do nervo, utilização de enxerto ósseo[12] antes ou simultaneamente à colocação do implante. No entanto, esses procedimentos exigem maior tempo cirúrgico e aumentam a morbidade do tratamento.

Para tentar resolver algumas situações limítrofes, como espaços interdentais estreitos - incisivos laterais superiores ou incisivos inferiores - e áreas com pouco volume ósseo, foram lançados no mercado os implantes de diâmetro reduzido (menor que 3.5mm de diâmetro). Estes implantes, quando bem indicados, possuem taxa de sobrevida comparável com os implantes de diâmetro regular.[25,33] Algumas características destes implantes podem ajudar a melhorar esta taxa de sobrevida: a interface cone Morse apresenta menor perda óssea inicial por manter o osso distante da área da junção pilar/implante[23] e por diminuir a contaminação bacteriana desta região.[22] Além disso, a modificação da liga de titânio puro pode melhorar o comportamento biomecânico das ligas.[24] Um bom exemplo são as ligas de Titânio-Zircônia (Ti-Zr) (Straumann, Basiléia, Suíça)[7,15] e a liga de Titânio-Alumínio-Vanádio (Facility, Neodent, Curitiba, Brasil).[24] Os implantes estreitos de Ti-Zr e os de Ti Grau IV apresentam uma alta taxa de sobrevida

(100%) em estudos que compreendem entre 1-3 anos de acompanhamento.[11,16] Implantes estreitos apresentam uma perda óssea dentro dos níveis aceitáveis, contudo, podem apresentar perdas ósseas maiores que os implantes regulares.[34]

Apesar de todas as vantagens descritas, alguns estudos relatam falhas ou insucessos quando utilizaram implantes estreitos como: infecção periimplantar,[14,18,25,31,33] falha na osseointegração[3,5] e fratura do corpo do implante.[31,33] Alguns trabalhos laboratoriais descrevem maior concentração de tensão no osso ao redor do implante [20,30] e maior deformação cervical em implantes estreitos.[10]

Em 2013 a Neodent lançou o implante Facility (Neodent, Curitiba, PR, Brasil), um implante ultra-estreito com 2.9mm de diâmetro, que foi desenvolvido para áreas com grandes perdas ósseas (inclusive para reabilitações implanto-retidas e mucosuportadas que apresentam grande reabsorção no sentido vestíbulo-lingual – overdentures) e para áreas de pouco esforço mastigatório (como incisivos laterais superiores e incisivos inferiores). Uma das suas características é uma interface com conexão protética Morse, sem parafusos internos, com o objetivo de preservar sua resistência e ao mesmo tempo evitar o estreitamento das paredes do implante, bem como sua liga de titânio grau V (Ti6Al4V) que é mais compacta e mais resistente. O presente trabalho tem como objetivo o relato de um caso clínico com a utilização do implante Facility, demostrando a solução de um caso limítrofe de forma segura clinicamente.

Relato do caso

Paciente de 21 anos, gênero masculino, estudante de Graduação em Odontologia pela Universidade Federal de Uberlândia, apresentava agenesia do elemento 32. Paciente encontrava-se em finalização de tratamento ortodôntico que tinha como um dos objetivos aumentar o pequeno espaço mésio-distal entre os elementos 31 e 33 para posterior instalação de implantes (Figura 1). Durante a anamnese não foi relatado nenhuma alteração na história médica do paciente. No exame clínico observa-se espaço para a instalação de implante de diâmetro ultra-estreito. Na tomografia volumétrica observou-se espaço de aproximadamente 5mm entre as raízes dos dentes vizinhos (Figura 2).

O tratamento proposto foi instalação de implante de 2.9mm de diâmetro (Facility, Curitiba, Brasil) cuja indicação é compatível com o caso apresentado.

O protocolo medicamentoso consistiu de Amoxicilina tri-hidratada 875mg uma hora antes da cirurgia e 1 comprimido a cada 12hs durante 7 (sete) dias e medicação analgésica no pós-operatório. Após assepsia e antissepsia extra e intra-oral foi realizada anestesia infiltrativa no tecido mole adjacente à área cirúrgica para descolamento do retalho e exposição do osso (Figura 3). A sequência de brocas utilizada foi Lança, Broca 2.0 e 14 do kit de instalação do implante Facility, sempre com irrigação abundante com soro fisiológico (Figuras 4, 5 e 6 respectivamente). A perfuração foi realizada com introdução leve, repetitiva, intermitente e vertical da broca no local de instalação. A profundidade e o paralelismo foram conferidos com o uso de um pino de paralelismo (Figura 7). Com o auxílio da conexão Facility para contra ângulo o implante foi instalado e o torque final com o torquímetro foi de 32N/cm (Figura 8). Foi instalado o implante de 14mm de comprimento, posicionado 1.5mm infra ósseo com um cicatrizador com altura de 2.5mm (Figura 9). Uma prótese provisória adesiva direta foi instalada ao final do procedimento cirúrgico (Figura 10).

Após o período de cicatrização de 6 meses, o paciente foi submetido à uma segunda etapa cirúrgica de reabertura para instalação do munhão anatômico de 1.5mm altura da forma como é preconizado pelo fabricante – três batidas com um martelete que é um dispositivo pneumático utilizado para instalação dos pilares neste sistema Morse (Figura 11). Nesta mesma sessão o munhão anatômico foi repreparado com brocas diamantadas para melhorar o contorno com relação à gengiva e um provisório foi confeccionado pela técnica de captura da faceta (Figura 12). A moldagem foi feita com silicone de Adição (Futura, AD, Nova DFL) por meio da técnica de duplo fio (Figura 13). Nesta sessão, também foi realizada a montagem dos modelos em Articulador Semi-Ajustável (ASA) para a confecção da coroa total metalocerâmica. Neste momento do tratamento, o paciente fez 2 sessões de clareamento com gel Calareador Potenza Bianco PRO (Peróxido de hidrogênio 38%). Após enceramento, prova do coping metálico e registro intermaxilar (Figura 14), foi realizada a moldagem de transferência para remontagem em ASA (Figura 15) e seleção de cor (Figura 16). Após a aplicação da porcelana, o paciente foi chamado para que fossem feitos os ajustes necessários: ajuste proximais, cervical, oclusal e de

anatomia para posterior glaze e instalação final (Figura 17). A peça foi cimentada com cimento fosfato de zinco.

Este caso clínico faz parte de um ensaio clínico randomizado aprovado pelo Comitê de Ética em Pesquisa sob nº: 44664615.4.0000.5152 e no Registro Brasileiro de Ensaios Clínicos sob nº: U1111-1224-1938.

Discussão

Quanto a sua configuração, o implante Facility foi desenvolvido com uma interface exclusiva cone Morse sem parafuso interno, evitando o estreitamento das paredes com a colocação de roscas internas, sendo este um dos possíveis fatores responsáveis por preservar a resistência mecânica dentro das suas indicações.[24]

Quanto ao comportamento clínico e a longevidade clínica de implantes estreitos com diâmetro < 3mm, Klein et al.[17] (2014) fizeram uma revisão sistemática e descreveram uma taxa de sobrevida entre 90.9% e 100%, com um tempo de acompanhamento entre 1 e 3 anos. Uma outra revisão sistemática, Brida; Almas[8] (2013) avaliaram a sobrevida de implantes cujos diâmetros variavam entre 1.8mm até 2.9mm e encontraram uma taxa de sobrevida de 94,7%.

Um estudo comparativo laboratorial de resistência à fratura com diferentes implantes estreitos disponíveis comercialmente (3.3mm, 2.8mm e 2.4mm de diâmetro comparados com um grupo controle de 4.1mm) concluiu que, implantes com diâmetro inferior a 3 mm, possuíram resultados significativamente inferiores comparado aos implantes do grupo controle, incluindo o implante de 3.3 mm de diâmetro da Straumann RN. Os autores sugerem que implantes estreitos sejam usados com cautela devido ao seu comportamento mecânico quando comparado com implantes de maior diâmetro, estando contraindicado o seu uso em regiões de grande esforço mastigatório.[2]

Em um estudo retrospectivo, foi analisado os resultados a longo prazo de implantes ultra-estreitos com diâmetro de 2.5 mm ferulizados aos implantes de diâmetro regular para suportar próteses fixas parciais e totais. Trinta e sete implantes (2.5 mm de diâmetro) foram instalados na maxila e na mandíbula de 20 pacientes. Os resultados demonstraram taxa de sobrevida de 97.3% com tempo mínimo de acompanhamento de 6 anos. Este resultado pode estar relacionado com o fato destes implantes estarem unidos a outros

implantes de diâmetro regular por uma prótese fixa. Esta configuração de prótese pode ter minimizado a probabilidade de falha do implante e prótese.[3]

Estudos que avaliaram reabilitações unitárias em áreas de pouco esforço mastigatório relatam taxas de sucesso que variam de 94.2% até 100% com tempos de acompanhamento de 1 até 5 anos.[14,18,21,27,28,32] Estes estudos instalaram implantes de 2.9mm e 3.0mm e as perdas ósseas descritas variam entre -0.065mm até -0.8mm. Estes resultados atestam uma boa taxa de sobrevida de implantes estreitos, mesmo com períodos de acompanhamento significativo, quando instalados de acordo com a recomendação dos fabricantes. Por outro lado, em trabalhos em que implantes estreitos são instalados em áreas de grandes esforços mastigatórios (extrapolando a indicação do fabricante), foram descritas fraturas do corpo do implante.[31,33] Estes trabalhos descreveram 4 fraturas de implantes, com um período de acompanhamento que variou entre 5 e 10 anos, respectivamente. O trabalho de Zinsli et al[33] (2004) descreveram uma fratura de implante de 3.3mm instalado em região de pré-molar aos 6 anos de acompanhamento. Yaltirik et al[31] (2011) relataram fratura de implante de 3.3mm instalados na região de molares com 5 anos de acompanhamento. Estes resultados sugerem que implantes estreitos instalados em regiões de grande esforço mastigatório depois de longo período em função tendem a falhar devido à fadiga.

Uma das vantagens dos implantes ultra-estreitos com diâmetro inferior à 3 mm é a solução de casos limítrofes e a possibilidade de reabilitação de dentes com diâmetro cervical reduzido como os incisivos laterais superiores e os incisivos inferiores,[18] como descrito neste relato de caso. Além disso, o seu uso pode reduzir ou evitar procedimentos mais invasivos como enxertos ósseos [6,12,33] e tratamento ortodôntico preliminar.[6] Pacientes idosos ou pacientes com fatores de risco médicos gerais podem se beneficiar desta terapia, porque diminui o risco de morbidade e também o tempo de tratamento.[17] Estudos epidemiológicos mostraram que os pacientes desdentados, especialmente idosos, não se sentem dispostos a submeter-se a procedimentos cirúrgicos.[9,19] Além disso, existem preocupações e restrições contra tratamentos demorados associados com complicações e dor. [13,29]

Conclusão

Implantes ultra-estreitos apresentam boas taxas de sobrevida e sucesso quando instalados em áreas de pouco esforço mastigatório, seguindo as recomendações do fabricante. Além do mais, estes implantes são excelentes opções para situações em que o espaço mésio-distal é reduzido, impedindo a instalação de implantes de diâmetro regular.

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LEGENDAS DE FIGURA

Figura 1 – Situação inicial do caso.

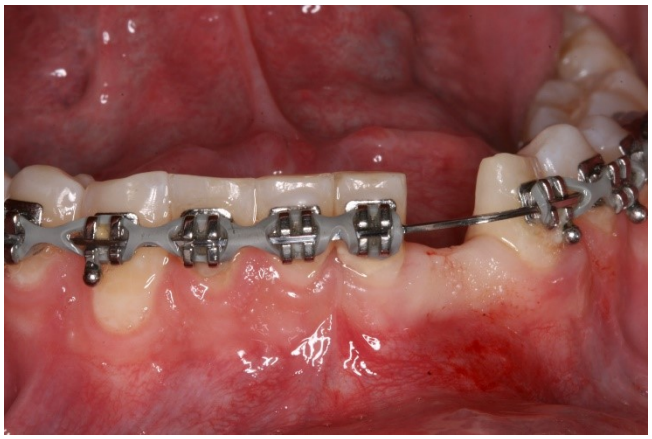


Figura 2 – Tomografia volumétrica.

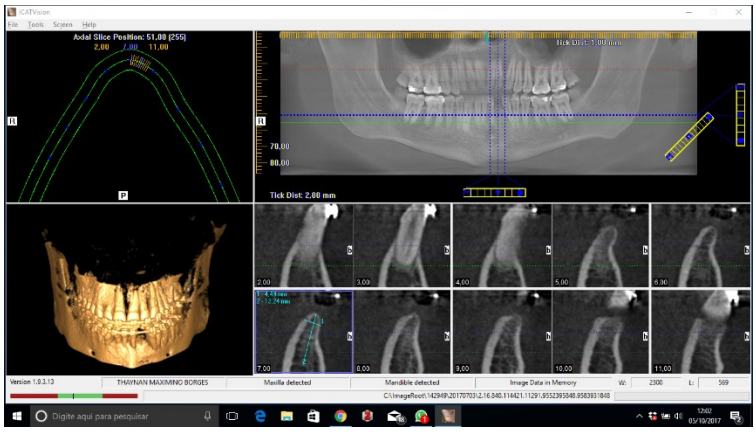


Figura 3 – Exposição do osso no leito cirúrgico.

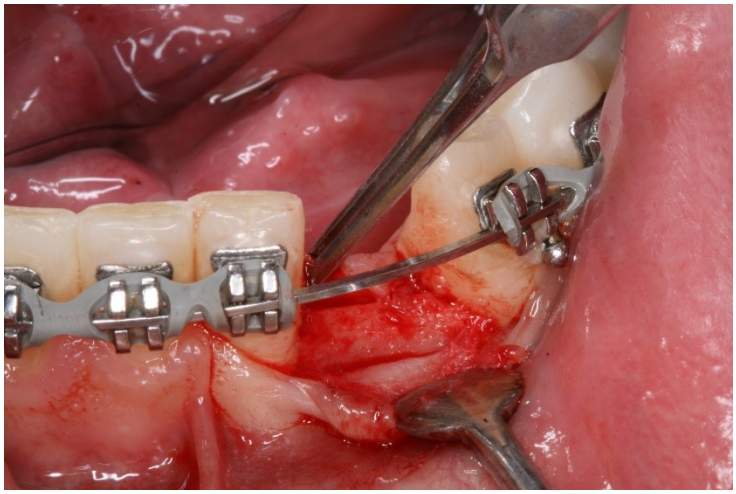


Figura 4 – Broca Lança do kit cirúrgico Facility.

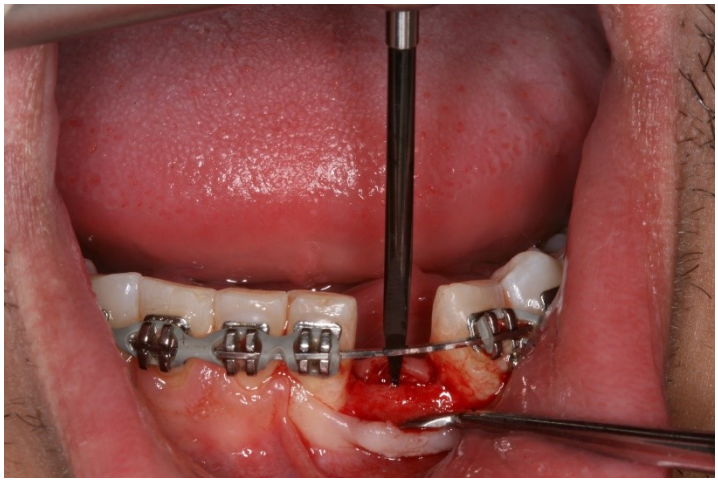


Figura 5- Broca 2.0 do kit cirúrgico Facility.

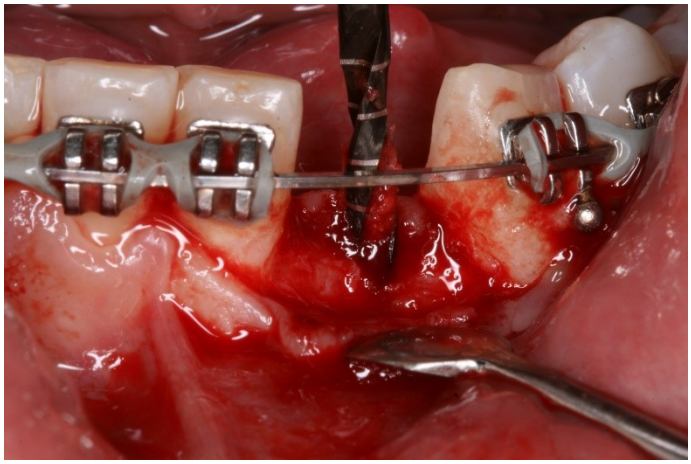


Figura 6 – Broca 14 do kit cirúrgico Facility.

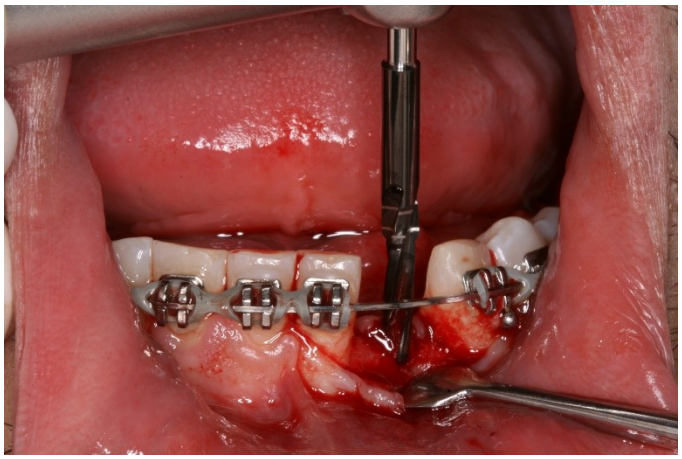


Figura 7 – Uso do pino de paralelismo para conferência da posição do implante.

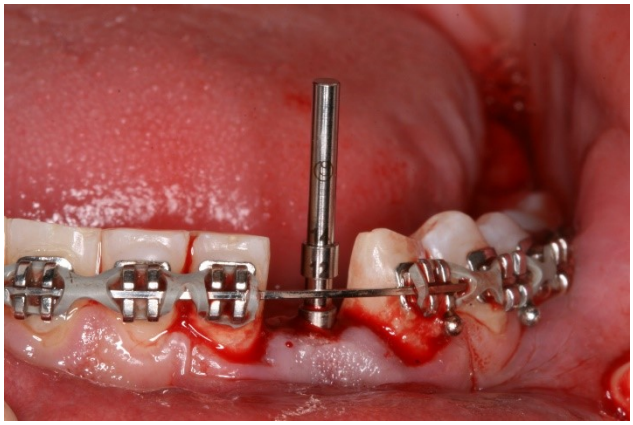


Figura 8 – Instalação do implante Facility de 14mm

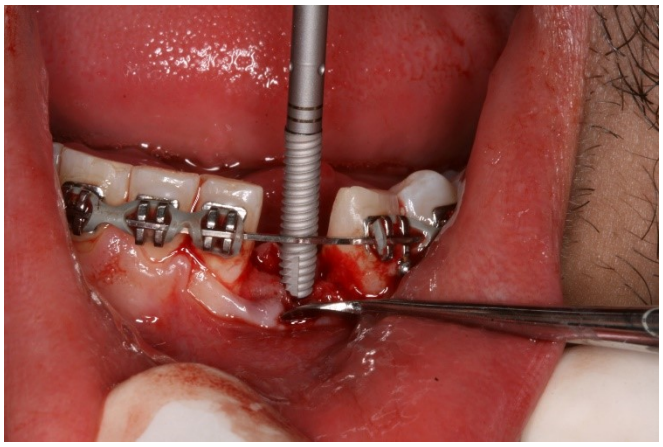


Figura 9 – Cicatrizador de 2.5mm instalado.

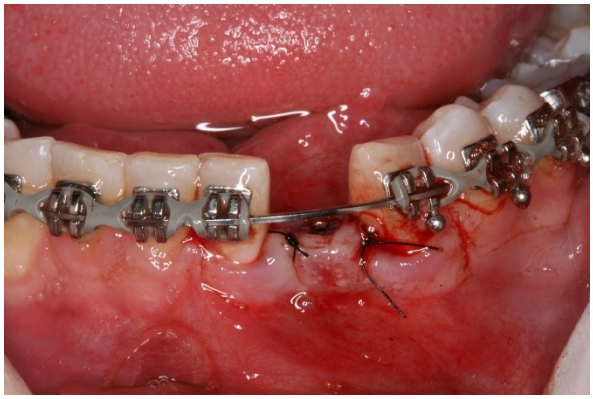


Figura 10 – Provisório confeccionado (prótese adesiva direta).

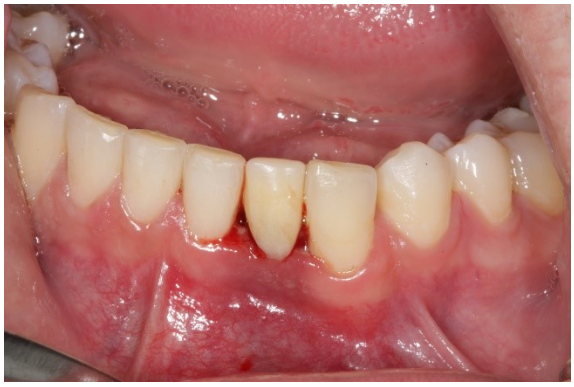


Figura 11 – Instalação do munhão anatômico Facility de 1.5mm de altura de acordo com a recomendação do fabricante

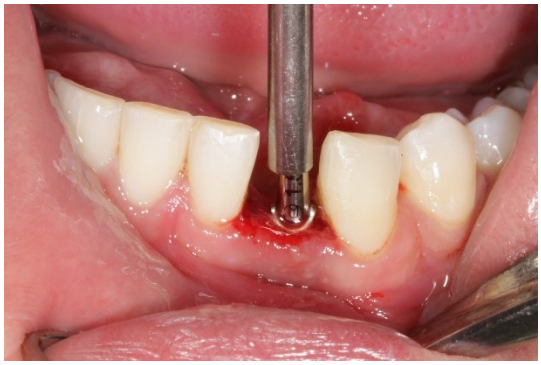


Figura 12 – Confecção de provisório por meio da técnica de captura da faceta.

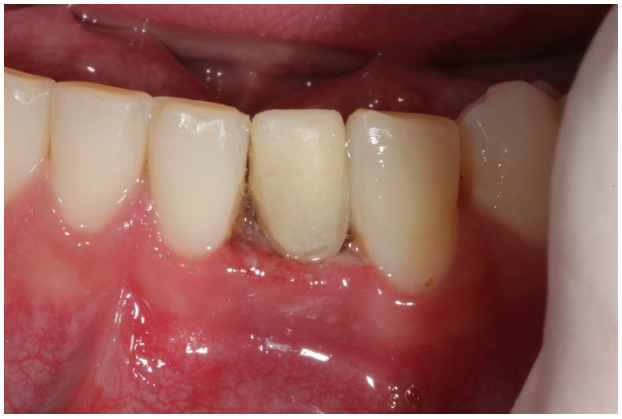


Figura 13 – Moldagem de trabalho.

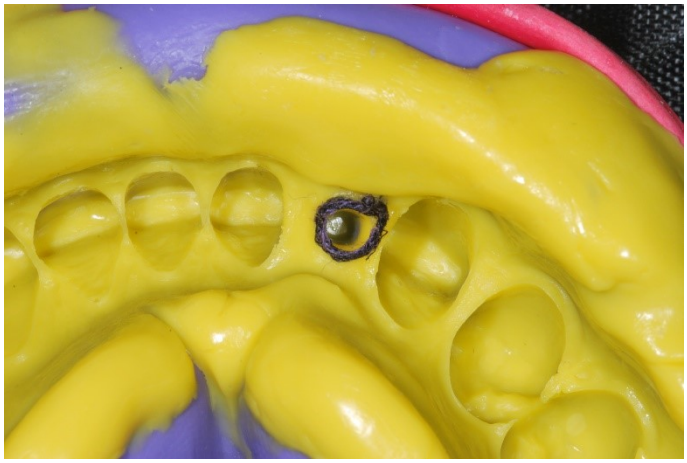


Figura 14 – Prova do coping metálico e registro intermaxilar

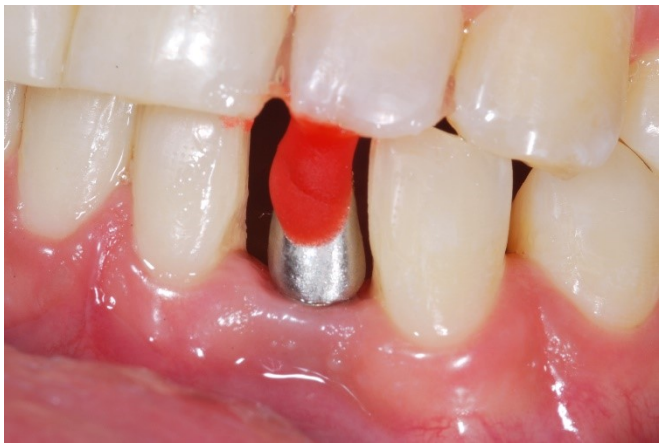


Figura 15 – Moldagem de transferência feita com alginato.

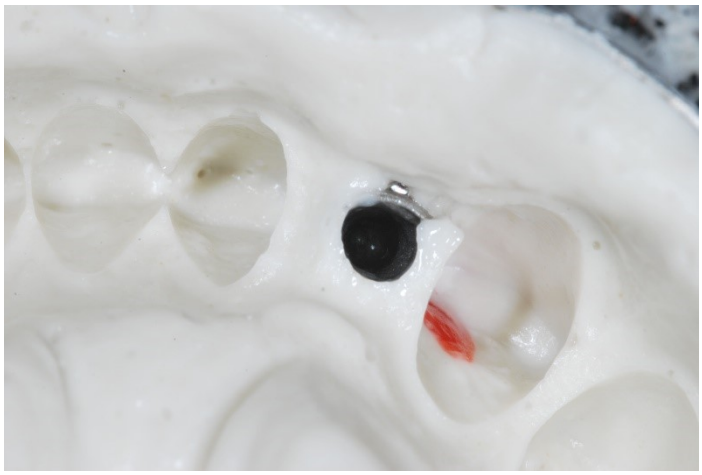


Figura 16 – Seleção de cor para aplicação de porcelana

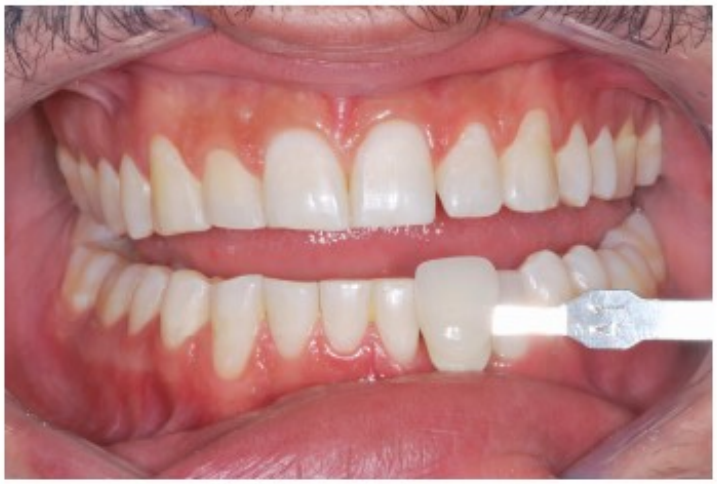
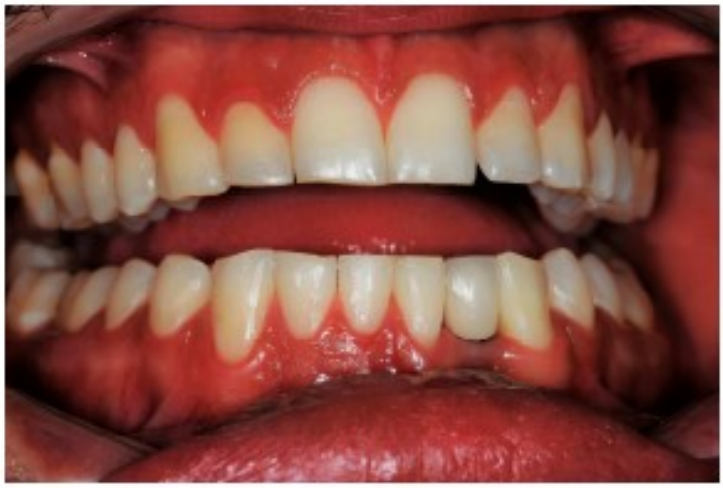


Figura 17 – Instalação final da cora total metalocerâmica



2. CONCLUSÕES

- A indicação de implantes estreitos deve ser feita de forma cautelosa, visto que estes possuem características biomecânicas e indicações muito específicas, além de serem biomecânicamente inferiores quando comparados com os implantes de diâmetro regular.
- Muitos estudos ainda relatam a instalação de implantes estreitos em regiões posteriores, o que pode resultar em fadiga destes implantes quando em função por um longo período.
- Algumas características do implante Facility (como a inclinação de suas paredes internas e sua conexão Morse) podem ter favorecido seu desempenho mecânico dentro de padrões clínicos aceitáveis para suas indicações.

3. *REFERÊNCIAS (Introdução e referencial teórico)*

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