Frederico Santos Lages

ESTABILIDADE EM IMPLANTES DENTÁRIOS: ANÁLISE DA FREQUÊNCIA DE RESSONÂNCIA E TORQUE DE INSERÇÃO

Faculdade de Odontologia

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Tese apresentada ao Colegiado do Programa de Pós-Graduação da Faculdade de Odontologia da Universidade Federal de Minas Gerais, como requisito parcial para obtenção do grau de Doutor em Odontologia - área de concentração em Periodontia.

Orientador: Prof. Dr. Fernando Oliveira Costa.
Co-Orientadora: Profa. Dra. Thallita Pereira Queiroz.

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PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

FOLHA DE APROVAÇÃO

ANÁLISE DA FREQUÊNCIA DE RESSONÂNCIA, ESTABILIDADE E TORQUE DE INSERÇÃO EM IMPLANTES DENTÁRIOS

FREDERICO SANTOS LAGES

Tese submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em Odontologia, como requisito para obtenção do grau de Doutor, área de concentração Periodontia.

Aprovada em 19 de setembro de 2017, pela banca constituída pelos membros:

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Belo Horizonte, 19 de setembro de 2017.

UNIVERSIDADE FEDERAL DE MINAS GERAIS

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

ATA DA DEFESA DE TESE DO ALUNO
FREDERICO SANTOS LAGES

Aos 19 dias de setembro de 2017, às 09:00 horas, na sala 3403 da Faculdade de Odontologia da Universidade Federal de Minas Gerais, reuniu-se a Comissão Examinadora composta pelos professores Fernando de Oliveira Costa (Orientador) – FO/UFMG, Thallita Pereira Queiroz (Coorientadora) – Universidade de Araraquara, Luiz Felipe Cardoso Lehman – UFMG, José Mauricio Santos Nunes Reis – Universidade Estadual Paulista, Cristiane Baccin Bendo – FO/UFMG e Luis Otavio de Miranda Cota – FO/UFMG, para julgamento da tese de Doutorado em Odontologia, área de concentração em Periodontia, intitulada: **Análise da frequência de ressonância, estabilidade e torque de inserção em implantes dentários.** O Presidente da Banca, abriu os trabalhos e apresentou a Comissão Examinadora. Após a exposição oral do trabalho pelo aluno e arguição pelos membros da banca, a Comissão Examinadora considerou a tese:

(✓) Aprovado

( ) Reprovado

Finalizados os trabalhos, lavrou-se a presente ata que, lida e aprovada, vai assinada por mim e pelos demais membros da Comissão. Belo Horizonte, 19 de setembro de 2017.

Prof(a). Fernando de Oliveira Costa

Prof(a). Thallita Pereira Queiroz

Prof(a). Luiz Felipe Cardoso Lehman

Prof(a). José Mauricio Santos Nunes Reis

Prof(a). Cristiane Baccin Bendo

Prof(a). Luis Otavio de Miranda Cota

“Amar e mudar as coisas me interessa mais.”

(Antônio Carlos Belchior)

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FAPEMIG – Fundação de Amparo a Pesquisa do Estado de Minas Gerais

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Aos meus pais, que sempre me ensinaram a levar a vida da melhor forma possível: com trabalho duro e sorriso no rosto!

Dedico também a todos os pacientes que necessitam do nosso atendimento. A busca incessante pelo conhecimento é para tentar fazer sempre o melhor para vocês.

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RESUMO

As pesquisas clínicas na área da implantodontia apresentam uma grande dificuldade em relação à avaliação da osseointegração e estabilidade dos implantes. Dessa forma, a análise de frequência de ressonância (AFR) têm se tornado uma das principais ferramentas utilizadas, já que oferece, de forma simples e não invasiva, a possibilidade de se monitorar a estabilidade durante todo o período desejado. Outra medida também bastante usada na prática clínica é o torque de inserção dos implantes. No entanto, essa medida é limitada ao trans-cirúrgico e nos fornece unicamente a estabilidade primária dos implantes, o que a torna mais indicada para avaliação da possibilidade de se submeter à carga imediata. Este estudo apresenta como objetivos avaliar, por meio de um estudo transversal, se os valores do coeficiente de estabilidade do implante (ISQ) são similares em diferentes alturas do componente protético e diretamente na plataforma, quando mensurados por meio da AFR e avaliar por meio de uma revisão sistemática e meta-análise a relação entre o torque de inserção e a AFR, investigando se estes dois instrumentos fornecem avaliações similares da estabilidade primária de em um mesmo implante. Para tal, foi realizado um estudo transversal em 31 implantes osseointegrados com plataforma de hexágono externo, com 4.1 mm de diâmetro e comprimento maior ou igual a 10mm e uma revisão sistemática com ensaios clínicos que reportassem valores de ISQ e torque de inserção. Assim, nossos estudos recomendam que explorar e desenvolver a AFR como método de avaliação da estabilidade implantar deve ser uma busca ainda necessária das pesquisas científicas para melhor compreensão do comportamento dos implantes dentários, nos seus diversos momentos e situações na cavidade oral, bem como determinar um bom nível de estabilidade que consequentemente determinaria uma maior longevidade e funcionalidade dos implantes dentários.

Palavras chave: Osstell; Análise Da Frequência De Ressonância; Torque de Inserção; Implantes Dentários.

ABSTRACT

Clinical research in the implantology presents a great difficulty regarding the evaluation of the osseointegration and stability of the implants. Thus, resonance frequency analysis (RFA) has become one of the main tools used, since it offers, in a simple and non-invasive way, the possibility of monitoring the stability during the desired period. Another measure also widely used in clinical practice is the insertion torque of the implants. However, this measure is limited to the trans-surgical and provides only the primary stability of the implants, which makes it more suitable for evaluating the possibility of undergoing immediate loading. This study aims to evaluate, through a cross-sectional study, whether implant stability coefficient (ISQ) values are similar at different heights of the prosthetic component and directly on the platform, when measured through RFA and evaluated by means of a systematic review and meta-analysis of the relationship between the insertion torque and the RFA, investigating whether these two instruments provide similar assessments of the primary stability of the same implant. For this purpose, a cross-sectional study was performed on 31 osseointegrated implants with external hexagon platform, 4.1 mm in diameter and length greater than or equal to 10 mm and a systematic review with clinical trials that reported ISQ values and insertion torque values. Thus, our studies recommend that exploring and developing RFA as a method of evaluating implant stability should be a still necessary search of scientific research to better understand the behavior of dental implants in their various moments and situations in the oral cavity, as well as to determine a a good level of stability which would consequently determine the greater longevity and functionality of dental implants.

Keywords: Osstell; Ressonance Frequence Analysis; Insertion Torque; Dental Implants.

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CONSIDERAÇÕES INICIAIS

As pesquisas clínicas na área da implantodontia apresentam uma grande dificuldade em relação à avaliação da osseointegração e estabilidade dos implantes. Dessa forma, a análise de frequência de ressonância (AFR) têm se tornado uma das principais ferramentas utilizadas, já que oferece, de forma simples e não invasiva, a possibilidade de se monitorar a estabilidade durante todo o período desejado (Nedir et al., 2004).

A AFR é mensurada por meio do aparelho Osstell®. Este aparelho utiliza transdutores conectados aos implantes ou aos componentes protéticos, disponíveis para diversos sistemas. Os transdutores (também chamados de *smartpegs*) imprimem uma força lateral fixa aos componentes e o deslocamento do sistema é, então, mensurado. Desse modo, a AFR mede a rigidez e a deflexão do complexo osso-implante (Griffin e Cheung, 2004). O valor obtido pelo Osstell® é automaticamente traduzido para um índice chamado de Coeficiente de Estabilidade do Implante (CEI) (ou *ISQ: Implant stability quotient*), que varia entre 1 e 100 (sendo 100 o maior valor de estabilidade) e nos permite também, avaliar a estabilidade ao longo do tempo e identificar as condições ósseas ao redor do implante (Meredith, Alleyne e Cawley, 1996; Xiao et al., 2012).

Diversos estudos investigaram a confiabilidade da AFR para medir a estabilidade do implante e confirmaram seu uso neste propósito (Meredith, 1998; Hayashi et al., 2010; Sim e Lang 2010; Simunek et al., 2012), sendo o valor de ISQ 70 considerado o limiar para a instalação da prótese (Kuchler et al., 2016)

No entanto, observamos na literatura correlação entre os valores de estabilidade do implante e o seu sucesso somente em medições realizadas diretamente na plataforma do implante, embora o próprio fabricante do Osstell® indique tipos específicos de transdutores para serem aplicados sobre os componentes protéticos (*abutments*). Devido aos transdutores imprimirem uma força lateral fixa aos componentes ou à plataforma do implante, quando a mensuração é realizada sobre o componente protético espera-se que o deslocamento seja maior, já que se aumenta o braço de alavanca em relação à medida efetuada diretamente na plataforma. Assim sendo, espera-se para o mesmo implante um valor menor de ISQ quando medido no componente, em relação ao valor medido diretamente na plataforma.

Deve ser ressaltado, que não há na literatura científica estudos que elucidem as questões acima descritas e que faça comparações entre os valores obtidos no componente e plataforma dos implantes.

Adicionalmente, é notório o fato de que após receberem o torque de apertamento, os componentes protéticos devem ser mantidos em posição e deve-se evitar sua remoção, pois esta pode ocasionar danos tanto às roscas dos implantes quanto aos próprios componentes, além de aumentar a contaminação bacteriana e perda do osso interproximal (Calcaterra et al., 2016; Molina et al., 2016).

Além disso, os estudos clínicos prospectivos de longo prazo em implantodontia geralmente se iniciam na fase cirúrgica e continuam sendo avaliados com a prótese em função, o que necessita da remoção da prótese para uma aferição precisa. No entanto, é expressamente contra-indicado a remoção do componente protético após a sua instalação, pois esta é uma das responsáveis pelo selamento bacteriano na interface implante componente.

Dessa forma, a correlação dos valores da AFR entre a plataforma do implante e os componentes protéticos, pode representar um enorme salto nas pesquisas longitudinais em implantodontia.

Tendo em vista os inúmeros estudos clínicos que empregam a análise de frequência de ressonância por meio do Osstell® para avaliação da estabilidade dos implantes e a ausência de artigos na literatura que correlacionem os valores obtidos na plataforma do implante e nos componentes protéticos, torna-se relevante um estudo que favoreça a padronização das mensurações e a interpretação dos resultados visando maior confiabilidade sobre a estabilidade de um implante e as respectivas próteses sobre os mesmos.

Outra medida também bastante usada na prática clínica é o torque de inserção dos implantes (Lozano-Carrascal et al., 2016). No entanto, essa medida é limitada ao trans-cirúrgico e nos fornece unicamente a estabilidade primária dos implantes, o que a torna mais indicada para avaliação da possibilidade de se submeter à carga imediata (Douglas de Oliveira et al., 2016).

Dessa maneira, investigar se há uma relação entre o torque de inserção e a AFR torna-se fundamental, tendo em vista a maior aplicabilidade da AFR e a contínua avaliação do comportamento do conjunto implante-osso ao longo do tempo.

LITERATURA CONSULTADA

A osseointegração é definida como uma conexão estrutural e funcional direta entre o osso vivo ordenado e a superfície de um implante submetido a carga. E o estabelecimento e manutenção dessa osseointegração são requisitos chaves para o sucesso dos implantes dentários (Branemark & Albrektsson, 1985). Já estabilidade do implante pode ser definida como o valor da micromovimentação relativa entre o implante dentário e o osso circundante (Trisi et al., 2016).

A estabilidade primária é aquela avaliada no momento de inserção do implante e é importante para permitir a formação de um osso sólido ao redor do implante, após o trauma causado pela cirurgia de instalação (Sakka et al. 2012). A falta dessa estabilidade pode gerar a formação de um calo fibroso, pois a micromovimentação ativa a atividade osteoclástica na interface osso-implante e consequente pode levar a falha no processo de osseointegração, (Meredith, 1998). Após a neoformação do osso peri-implantar, os implantes atingem a estabilidade secundária, que reflete o valor do reforço da conexão mecânica entre implantes e ossos induzidos pelo processo de osseointegração (Trisi et al., 2016).

A estabilidade dos implantes ganhou mais atenção e extensa pesquisa científica na última década, pois também é fator crucial para a técnica de carga imediata (Lozano-Carrascal et al., 2016; Trisi et al., 2016).

Clinicamente, a estabilidade primária pode ser avaliada pelo torque de inserção do implante ou pela análise de frequência de ressonância (AFR), enquanto a estabilidade secundária pode ser avaliada pelo torque reverso de

20N/cm ou também pela AFR (Sullivan et al., 1996; Zix et al., 2008; Hayashi et al., 2010). O torque de inserção tem uma grande desvantagem, que a medida só pode ser realizada em um único momento – na instalação do implante -, enquanto a RFA pode ser realizada em todas as fases do tratamento (Levin, 2016).

Ainda há uma falta de consenso na literatura sobre quando a estabilidade secundária é suficiente para suportar com segurança a carga oclusal adequada, pois ela é afetada por diversas variáveis como densidade óssea, geometria e superfície implantar, técnica cirúrgica e condições de carga durante a cicatrização (Simunek et al., 2012; Xiao et al., 2012). E, além disso, essas variáveis poderiam modificar, de forma significativa, o tempo necessário para atingir a estabilidade secundária (Trisi et al., 2016).

O torque reverso e o contato osso-implante (COI) fornecem uma análise quantitativa em relação à estabilidade secundária e osseointegração do implante, mas não são clinicamente aplicáveis, pois são destrutivas para a interface osso-implante (Steigenga et al., 2004).

A AFR possibilita, de forma simples e não invasiva, o monitoramento da estabilidade dos implantes dentários e o comportamento e prognóstico dos mesmos, tanto durante o período de cicatrização, quanto após entrarem em função (Meredith, 1998; Nedir et al., 2004; Ramakrishna e Nayar, 2007).

Diversos estudos clínicos demonstraram que esse método pode ser utilizado para se determinar o momento ideal para se iniciar a confecção da prótese sobre implante, ao invés de se limitar a aguardar um tempo pré-determinado. (Valderrama et al., 2007; Fischer et al., 2009; Bornstein et al., 2010;

Sim e Lang 2010; Simunek et al., 2012). O Osstell® (Göteborg, Suécia) é o único aparelho atualmente disponível para se realizar a mensuração da AFR, e ele traduz automaticamente esta medição em um índice chamado de Coeficiente de Estabilidade do Implante (CEI ou *ISQ: Implant stability quotient*), que varia entre 1 e 100 (Meredith, Alleyne e Cawley, 1996; Xiao et al., 2012), sendo o valor de ISQ 70 considerado o mínimo para a instalação da prótese (Kuchler et al., 2016).

Na escala utilizada pelo Osstell®, os implantes que apresentam valores de ISQ menores que 60 são considerados com baixa estabilidade, os que apresentam valores entre 60 e 69 são considerados com média estabilidade e valores de ISQ maiores que 70 são considerados alta estabilidade dos implantes (Meredith, 1998).

Outros dispositivos já foram propostos para avaliar a estabilidade primária dos implantes, como Periotest (Siemens-Gulden, Bensheim, Germany) e Dental Fine Tester (Kyocera, Kyoto, Japan), mas apresentaram sensibilidade pobre e muita variação em relação à operadores (Meredith, 1998). O Periotest foi inicialmente desenvolvido para avaliar mobilidade dentária, mas apesar de diversos autores proporem o seu uso para avaliar estabilidade dos implantes (Schulte & Lukas 1993) esse método também se mostrou controverso por não ter um ponto fixo de aplicação e com isso não se torna reproduzível e comparável (Hobkirk & Wiskott 2006).

Ohta et al. (2010) avaliaram a AFR sobre diversos aspectos, mas sempre mensurando diretamente na plataforma dos implantes. O seu estudo mostrou que o diâmetro do implante e a direção da medição (perpendicular ou paralela) em relação ao *smartpeg* não alteram significantemente o valor de ISQ. A única correlação estatisticamente significante foi entre o torque de inserção e os valores de ISQ. Choi et al. (2014) sugeriram que o Osstell® pode ser usado para diagnóstico da estabilidade do implante e avaliação da perda óssea circular. Mas para defeitos ósseos parciais eles consideram que as medições são pouco precisas.

Andreotti et al. (2016) realizaram uma revisão sistemática com o objetivo de investigar se os dois métodos usados para avaliar a estabilidade dos implantes (Osstell e Periotest) fornecem resultados similares de estabilidade, quando utilizados nos mesmos casos clínicos. Para tal, as pesquisas foram realizadas nas bases MEDLINE-Pubmed e Scopus, sem restrições e com artigos publicados até novembro de 2015. As palavras chave por eles utilizadas foram "dental implant", "dental implants", "Osstell", "resonance frequency analysis", "implant stability quotient", "ISQ", "Periostest", "Periotest value" e "PTV" e a questão PICO foi determinada de acordo com o PRISMA, sendo a população pacientes reabilitados com implantes, a intervenção foi a avaliação da estabilidade do implante, a comparação foi a avaliação da estabilidade dos implantes através dos dispositivos Osstell e Periotest e o resultado avaliado foi a presença de uma interrelação entre a estabilidade dos implantes, registrado por essas duas diferentes técnicas. Essa revisão sistemática mostrou que não há um consenso e padronização nas medidas e classificação da estabilidade dos implantes pelos dispositivos Osstell e Periotest, sendo que somente 46% dos casos foram concordantes entre si. Segundo o artigo, apesar de não haver uma concordância entre os métodos ambos podem ser confiáveis, mas ao avaliar o progresso do paciente a longo prazo, o mesmo dispositivo deve ser sempre utilizado nas medições, pois os resultados obtidos pelos diferentes dispositivos não podem ser comparados.

Uma limitação do Osstell® é requerer um transdutor específico para cada tipo de implante e componente e esses não estão disponíveis para todas as marcas encontradas no mercado (Andreotti et al., 2016). Além disso, em próteses do tipo cimentadas o aparelho tem seu uso limitado devido às dificuldades de se remover a prótese para se realizar as mensurações (Zix et al., 2008; Choi et al., 2014).

Em adição, métodos quantitativos da avaliação da estabilidade do implante devem ser complementares a outros métodos de análise, como exames clínicos e radiográficos. Além dos valores de ISQ, devem-se observar características como falta de mobilidade clínica, ausência de dor, ausência de parâmetros clínicos de infecção peri-implantar (supuração, sangramento e profundidade de sondagem alterada) e bom aspecto radiográfico sem grandes áreas radiolúcidas ao redor do implante, pois são parâmetros clínicos básicos que definem o sucesso do implante ao longo do tempo (Andreotti et al., 2016; Griffin e Cheung, 2004).

OBJETIVOS

Este estudo apresentou dois objetivos principais:

1. Avaliar, por meio de um estudo transversal, se os valores do coeficiente de estabilidade do implante (ISQ) são similares em diferentes alturas do componente protético e diretamente na plataforma, quando mensurados por meio da análise de frequência de ressonância (AFR).

Especificamente:

1.1. Determinar as possíveis diferenças entre os valores de ISQ obtidos diretamente na plataforma dos implantes e nos componentes protéticos;

1.2. Verificar se há uma correlação entre a altura dos componentes e os valores de ISQ;

1.3. Avaliar se a escala de estabilidade dos valores de ISQ é adequada para as diferentes alturas de componentes protéticos.

2. Avaliar por meio de uma revisão sistemática e meta-análise a relação entre o torque de inserção e a AFR, investigando se estes dois instrumentos fornecem avaliações similares da estabilidade primária de em um mesmo implante.

HIPÓTESES

- O valor de ISQ de um mesmo implante pode variar em função do ponto que se realiza a medida: diretamente na plataforma ou no componente protético;

- Em um mesmo implante, quanto maior a altura do transmucoso do componente protético, menor o valor de ISQ.

METODOLOGIA EXPANDIDA

- Desenho do estudo

Foi realizado um estudo transversal em 31 implantes osseointegrados com plataforma de hexágono externo, com 4.1 mm de diâmetro e comprimento maior ou igual a 10mm.O estudo foi aprovado pelo Comitê de em Pesquisa com Seres Humanos (COEP) da Faculdade de Odontologia da Universidade Federal de Minas Gerais – protocolo 57216016.6.0000.5149 (Anexo 1) e conduzido de acordo com a Declaração de Helsinki de 1975, revisada em 2013. Os participantes assinaram um Termo de Consentimento Livre e Esclarecido antes do estudo (Anexo 2).

- Estratégia amostral e seleção de participantes

Para determinar o tamanho da amostra, o cálculo para estimativas de parâmetros (coeficiente de relação) foi usado (Miot HA, 2011). O coeficiente de correlação (0.2) foi obtido de um estudo prévio utilizando a análise de frequência de ressonância (AFR) em ensaio clínico (Lozano-Carrascal et al., 2016). Cálculos com um nível de significância de 95% e poder de 80% determinaram que um mínimo de 25 implantes seria suficiente para detectar uma diferença de 5 unidades no quociente de estabilidade do implante (ISQ) entre os grupos.

Todas as avaliações foram realizadas por um único examinador (F.S.L.), que foi treinado e calibrado pelo método de teste/re-teste e o coeficiente de correlação intra-classe foi 0,98.

Os indivíduos que participaram da pesquisa foram selecionados no curso de Mestrado em Implantodontia do Centro Universitário de Araraquara

(UNIARA), São Paulo. Dentre os 72 indivíduos disponíveis foram selecionados, aleatoriamente por sorteio, 12 pacientes que apresentavam os seguintes critérios de inclusão: área posterior mandibular uni ou bilateral edêntula e que receberam implantes de conexão hexágono externo, 4.1 mm de diâmetro (plataforma regular) e comprimento maior ou igual a 10mm (implantes convencionais), em um estudo prévio realizado (Queiroz et al., 2015). Os 12 pacientes contribuíram com um total de 31 implantes. Os implantes não apresentavam alterações clínicas e radiográficas de infecções peri-implantares, com ausência de sangramento e sem profundidade de sondagem alterada, supuração e defeitos ósseos. Todos os pacientes selecionados passaram pela segunda fase cirúrgica, e estavam reabilitados com provisórios fixos aparafusados sobre implantes há pelo menos 14 dias.

- Considerações éticas

Os pacientes que preencheram os critérios de inclusão assinaram um Termo de Consentimento Livre e Esclarecido e ao final da pesquisa foram reabilitados com próteses metalo-cerâmicas sobre esses implantes no próprio curso de Mestrado em Implantodontia da UNIARA.

- Procedimentos clínicos e coleta de dados

O estudo foi iniciado com a remoção dos provisórios sobre implantes e dos componentes protéticos. A AFR foi usada por meio do aparelho Osstell® (Göteborg, Suécia) para mensurar o ISQ dos implantes. Assim, foi realizado a instalação do transdutor chamado *“smartpeg”* (transdutor de 1 cm comercialmente calibrado e fabricado – McLarnon et al., 2014) tipo 1, com torque manual, de aproximadamente 4 a 6 N.cm, direto na plataforma do implante, segundo as instruções do fabricante (G1). Em todos os *smartpegs* as aferições foram realizadas em quatro sentidos: mésio-distal, disto-mesial, vestíbulo-lingual e línguo-vestibular. O valor obtido pelo Osstell® é automaticamente transformado pelo aparelho em valores de ISQ, que variam de 1 a 100. Após a medição o *smartpeg* foi desparafusado.

Procedemos à instalação do componente do tipo *microuni*t, com transmucoso de 1mm (G2), que recebeu torque de 20N com catraca manual. Neste componente foi instalado o *smartpeg* tipo A3, com torque manual, de aproximadamente 4 a 6 N.cm e todas as aferições foram realizadas. Após a medição, o *smartpeg* foi desparafusado, assim como o *microunit* de 1mm.

Ainda no mesmo implante, foi instalado então um componente do tipo microunit, com transmucoso de 5mm (G3), que recebeu torque de 20N com catraca manual. Neste componente foi instalado o *smartpeg* tipo A3, com torque manual, de aproximadamente 4 a 6 N.cm e todas as aferições foram realizadas. Após a medição, o *smartpeg* foi desparafusado e posteriormente o componente do tipo *microunit.*

O provisório foi reinstalado no implante e o orifício de parafusamento foi vedado com tira de poliéster e o restaurador provisório Bioplic (Biodinâmica, Ibiporã, Paraná, Brasil).

ARTIGO 1

Os resultados, discussões e conclusões deste estudo serão apresentando no formato de um artigo científico intitulado: “Relationship between implant stability on the abutment and platform level by means of resonance frequency analysis: a cross-sectional study”

PLOS ONE

RESEARCH ARTICLE

Relationship between implant stability on the abutment and platform level by means of resonance frequency analysis: A cross-sectional study

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Abstract

Resonance frequency analysis (RFA) has become the main tool used to assess the osseointegration of dental implants. The objective of this study was to verify the relationship between the ISQ values with different prosthetic abutments and with the implant platform. The hypothesis was that ISQ values changes according to the abutment height. Twelve patients were included, whose contribution to the study was 31 dental implants (external hexagon connection implants, 4.1x10 mm). The temporary implant-supported crown and prosthetic components were removed and the following smartpegs were inserted, one at a time: type 1, in the implant platform (G1); type A3, in the microunit component with 1mm transmucosal height (G2) and type A3, in the microunit component with 5mm transmucosal height (G3). In all the smartpegs, RFA measurements were taken on mesial, distal, buccal and lingual surfaces. All evaluations were performed by a single calibrated examiner (ICC = 0.989). Data were analyzed by Friedman and Spearman correlation tests and log-linear marginal regression ($p<0.05$). The mean age of participants was 52.83 (± 3.77) years. There was statistically significant difference ($p<0.001$) among the mean ISQ of G1 (88.27 ±5.70); G2 (72.75 ±4.73) and G3 (66.33 ±3.67). There was statistically significant negative correlation between the ISQ and the measurement distance (rs:-0.852; $p<0.001$; R2:0.553). Measurement distance was significantly associated ($p<0.001$) with ISQ value in the log-linear regression. The abutment height has a significant impact on resonance frequency analysis measurements. The higher the transmucosal abutment height, the lower the implant stability quotient value. Clinically, the ISQ measured on the abutment cannot be compared with values measured on the implant platform.

Competing interests: The authors have declared that no competing interests exist.

Introduction

In clinical research in implantology, there is great difficulty in assessing the osseointegration of implants. Nowadays, resonance frequency analysis (RFA) has become the main tool used, as it is a simple and noninvasive method that makes it possible to monitor implant stability throughout the required period [1].

RFA is measured by the Osstell® device. This device that uses transducers connected to the implant or prosthetic components is available for various systems. The transducers (smart-pegs) print a lateral force on the fixed components and the system shift is then measured. Thus, RFA measures the stiffness and deflection of the implant-bone complex [2]. The value obtained by Osstell® is automatically translated into an index called the Implant stability quotient (ISQ), ranging from 1 to 100 (with 100 being the highest stability), and also allows stability to be evaluated over time, and to identify the conditions of bone around the implant [3,4]. In clinical practice, the implant stability can mainly be tested indirectly. However, caution should be exercised when judging implant systems exclusively on the basis of RFA and torque measurement [5].

The Osstell® can be used at the time of implant insertion, during the healing period, and with the prosthesis in function [6].

Several clinical studies have demonstrated the reliability of this method for determining when to start loading on the implant [7–11], and the value of ISQ 70 is considered the threshold for insertion of the prosthesis [12].

However, in the literature, relationship between implant stability and success values have been observed only in measurements made directly on the implant platform, although the manufacturer of Osstell® has indicated specific types of transducers to be applied to the prosthetic component (abutment). Nevertheless, there is no scientific evidence that elucidates the questions about this topic and allows comparisons to be made between these values.

Furthermore, it has been evident that after receiving the tightening torque, the prosthetic components must be held in position, and their removal must be prevented, because this may cause damage to both the threads of the implant and of the components themselves.

Considering the several clinical studies that have used resonance frequency analysis by means of Osstell® to evaluate the stability of implants, and the absence of articles in the literature correlating the values obtained in the implant and abutment, the proposed study is a fundamental step towards facilitating the standardization of measurements and interpretation of the results obtained in each abutment.

The objective of this study was to verify the relationship between the ISQ values with different prosthetic abutments and with the implant platform. The hypothesis investigated was whether ISQ values changes according to abutment height and implant platform, at the same dental implant.

Material and methods

Sample size

This study was approved by the Ethics Committee on Human Research of Federal University of Minas Gerais under protocol 57216016.6.0000.5149. It was conducted in accordance with Declaration of Helsinki of 1975, revised in 2013. The participants signed a term of Free and Informed Consent before the study.

To determine the sample size, the calculation for correlation coefficient was used. The standard deviation (0.2) was obtained from a previous study using RFA in clinical trial [13]. The calculation, considering a 95% significance level and 80% power, determined that a minimum of 25 implants would be sufficient to detect a difference of 5 units in the implant stability quotient (ISQ) between groups.

All evaluations were performed by a single examiner (FSL). This researcher was trained and calibrated by the test-retest method, and the intraclass coefficient correlation was 0.989.

The patients were selected randomly among those who participated in a previous study [14], between February and April 2016. The inclusion criteria were: patients who were unilaterally or bilaterally edentulous in posterior mandibular area, with external hexagon connection implants, 4.1 mm in diameter (regular platform) and an implant length greater than or equal to 10mm (conventional implants). All patients eligible for selection had to have undergone the second surgical procedure and had to be rehabilitated with fixed provisional screw-retained implants. Patients who had mucositis, peri-implantitis and/or signs of bruxism were excluded from the sample.

Patients who met the inclusion criteria were required to sign a term of free and informed consent, and at the end of the treatment would be rehabilitated with metal-ceramic prosthesis on these implants.

RFA evaluation

The study began with the removal of temporary implant-supported crown and prosthetic components. Firstly, the type 1 smartpeg was inserted with manual torque of approximately 4 to 6 N.cm directly in the implant platform (G1), in accordance with the manufacturer's instructions (Osstell, Göteborg, Sweden). In all the smartpegs (Fig 1), measurements were taken in four directions: mesial, distal, buccal and lingual.

The value obtained by Osstell® was automatically transformed into ISQ values, ranging from 1 to 100. After measurement, the smartpeg was unscrewed. After this, the microunit type component with a transmucosal height of 1mm (G2) was inserted and received 20N torque applied with a manual ratchet. In the microunit, smartpeg component type A3 was inserted with manual torque of approximately 4 to 6 N.cm and all measurements were taken. After measurement, the smartpeg and the 1 mm microunit were unscrewed.

Subsequently, a microunit with a transmucosal height of 5mm was inserted in the same implant (G3), and received 20N torque applied with a manual ratchet. The smartpeg type A3 was inserted with a manual torque of approximately 4 to 6 N.cm and all measurements were taken. After measurement, the smartpeg and the microunit type component were unscrewed.

The provisional prosthesis were reinserted on the implant; the screw hole was sealed with a polyester strip and the provisional restorative Bioplic (Biodinâmica, Ibiporã, Paraná, Brazil).

Data analysis

Statistical analysis was performed by the R software (3.2.4 version) with a 5% level of significance. The Kolmogorov-Smirnov test showed non-normal data distribution. The Friedman test was used for inter-group comparisons. The Wilcoxon post-hoc test with Bonferroni correction ($p<0.016$) were used. The relationship between the ISQ values and measurement distances was verified by Spearman correlation.

To quantify the influence of the distances in the mean level of ISQ, the GEE (Generalized Equations Estimating) [15] model was used. This method is suitable to include the existing correlation between repeated measures. The GEE method is known as Marginal Models and can be considered as an extension of the Generalized Linear Models [16] which directly incorporate the correlation between the measurements of the same sample unit. The use of Marginal models has been preferred as an extension of Generalized Linear Models due to its easy

Fig 1. Resonance frequency analysis by Osstell. A) Implant platform B) 1mm microunit C) 5mm microunit.

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interpretation and lack of probability distribution assumption [17]. The $\sqrt{}$distance was used as predictor variable in the regression model.

Results

Twelve participants (05 men, 07 women), mean age 52.83 (± 3.77) years (range from 47 to 60), contributed 31 dental implants to the study. The mean ISQ for G1 was 88.27 (±5.70); G2, 72.75 (±4.73) and G3, 66.33 (±3.67). There was statistical significant difference among groups (Table 1). The abutments were inserted and removed without complication.

There was statistically significant negative correlation between the ISQ values and the measurement distance (r_s:-0.852; $p<0.001$; R^2:0.553). The measurement distance was significantly associated (B: 0.88, $p<0.001$) with ISQ value in the univariate regression analysis (Table 2).

Discussion

The RFA is the main method used for evaluating implant stability in long-term studies. These studies generally begin with surgical insertion of the implant and evaluations continue through to function of the prosthesis [18]. Ideally, the implant-supported prosthesis requires an abutment because of all the benefits it brings. However, after the abutments have been inserted, their removal is strongly contraindicated, because this breaks the bacterial seal at the implant interface component [19]. Furthermore, abutment removal can damage the threads of the implant, the abutment itself, and even cause loss of the prosthesis [20].

Therefore, long term studies of the behavior of dental implants have performed RFA measurements of both platforms and abutments. However, these values cannot be compared because they are not the same as the values shown in this study.

Because the transducers fixed to components or implant platform (2) print the lateral force on the prosthetic component when the measurement is performed, the displacement is expected to be larger, since it increases the lever arm in relation to the measurement made directly on the platform. Thus, when the ISQ component is measured, a lower value is expected for the same implant, compared with the value measured directly on the platform.

Table 1. ISQ comparisons among groups.

Group	Mean (SD)	Friedman test	Post-hoc test
Platform (G1)	88.27 (5.70)		G1XG2: <0.001
1mm (G2)	72.75 (4.73)	<0.001	G1XG3: <0.001
5mm (G3)	66.33 (3.67)		G2XG3: <0.001

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Table 2. Log-linear regression of the variable that predicts the ISQ value.

Variable	β	Exp(β)	C.I—95%	P-value
Intercept	4.46	-	-	-
√Distance	-0.13	0.88	[0.87; 0.89]	<0.001

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In the present study, two micro unit abutments with the lower and higher transmucosal heights available (1 and 5mm) were selected for each implant, and we observed that the more the transmucosal heights increased, the lower was the ISQ value. Moreover, all the values on the abutments were lower than those on the implant platform, for the same implants.

The abutments selected for the study were of the microunit type, due to the nature of screw-retained prostheses. The sample with external hexagon implants was chosen, because removal of the abutments was worse and less indicated for the Morse cone type. Futures studies are necessary to investigate the behavior of the ISQ values in dental implants with Morse cone connections.

[21] Evaluated the RFA from various aspects, but always took measurements directly on the implant platform. Their study showed that the diameter of the implant and the direction of measurement (parallel or perpendicular) relative to smartpeg did not significantly alter the ISQ value. The only statistically significant correlation found was between insertion torque and ISQ values. [22] Suggested that Osstell® can be used for diagnosis of implant stability and evaluation of circular bone loss. But for partial bone defects they believed that the measurements were inaccurate.

Some articles have reported the comparison between the ISQ measured on the abutment and the value measured directly on the implant platform [23–27]. In the present study, the log-linear marginal regression indicated that each unit increased in the square root of the smartpeg height, tended to decrease about 12% the mean ISQ value. The findings of this study suggest that the ISQ values obtained on the abutment cannot be compared with the platform values. This statement must be justified by the fact that the abutment has a transmucosal height, and consequently the force would be applied at a distance from the implant platform. As regards this result, the higher the abutment height, the lower the ISQ tended to be. Therefore, the ISQ values measured directly on prosthetic abutments in longitudinal studies were lower than the baseline ISQ values. These comparisons of ISQ results should be considered tilted. The authors of the present study suggest that to report and compare ISQ, studies should do this in a standardized way, always measured in the same place (either on platforms or abutments).

A scale has been established that correlates the ISQ value with the stability of the implant, determining ranges of values as a prognosis for success of the implant. However, the results obtained in this study, demonstrated that the ISQ varies relative to where this measurement is made. For the scale values, it should be clear where the measurement was made, and if measured on different abutments, it must be stated which the benchmarks were. Another methodological implication is that as the abutment transmucosal height increases, a lower ISQ value is expected, which may not reach the value of 100 proposed as the maximum value of RFA [28,29]. Consequently, a lower ISQ value can be considered ideal and/or maximum according to the component on which it was measured.

The RFA (by means of ISQ) is more sensitive for detecting changes in implant stability than the conventional clinical and radiological examinations. It is possible to detect the loss of stability before clinical signs/symptoms including pain and mobility. When the problem is diagnosed in time, the adoption of prudent measures could revert the drop in RF values [30,31]. Given the clinical importance and the present results, it is important to standardize the measurement place (or equivalence between measurements) of ISQ values in order to allow longitudinal monitoring of the implant, and not to make misleading comparisons (e.g., measurement on the platform at baseline compared with measurement on the abutment at follow-up), leading to false diagnoses and consequently an under- or over-treatment.

Thus, the relationship between RFA values and the implant platform and the prosthetic components may represent a huge advance in longitudinal research in implantology.

This study may present limitations, such as the use of only external hexagon implants. The authors suggest that further studies must be conducted with different diameters and implant connection, and different components to confirm the present findings, or not. They also suggests that studies should be developed to establish a mathematical formula for equating the ISQ value measured on the platform and at different transmucosal abutment heights. New scales of values for each ISQ and transmucosal abutment height should be further investigated.

Conclusion

The abutment height had a significant impact on resonance frequency analysis measurements. The higher the transmucosal abutment height, the lower was the implant stability quotient value.

In clinical practice, it is suggested that the ISQ measured on the abutment cannot be compared with values measured on the implant platform.

Supporting information

S1 Table. ISQ comparisons among groups.
(DOCX)

S2 Table. Log-linear regression of the variable that predicts the ISQ value.
(DOCX)

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Formal analysis: Frederico Santos Lages.

Investigation: Frederico Santos Lages, Guilherme Siqueira Ibelli, Fatimah Assaf, Fernando Oliveira Costa.

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ARTIGO 2:

Relationship between Implant Stability Measurements Obtained by

Insertion Torque and Resonance Frequency Analysis: A Systematic Review and Meta-analysis

Running title: Implant Stability Quotient and Insertion Torque

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Keywords: Dental implant, torque, osseointegration, osstell

Abstract

Background: The primary stability of dental implants can be evaluated by insertion torque and resonance frequency analysis (RFA).

Objective: Assess the supposed relationship between the insertion torque and RFA.

Material and methods: A systematic review was performed based on the PRISMA. The electronic search was performed in the PubMed, Web of Science, SCOPUS, Cochrane Library electronic, OVID and Scielo databases. Manual searches were also performed. There was no restrictions regarding year of publication or language. The articles identified were assessed independently by three trained researchers. Clinical trials reporting the RFA values by means of implant stability quotient (ISQ) and insertion torque were included.

Results: The electronic and manual searches yielded 2017 studies. 12 studies were included in the systematic review. There was no statistically significant correlation between ISQ and insertion torque (rs=0.366; p=0.079). The quality of the evidence was downgraded by risk of bias and indirectness; and the certainty of the evidence was low.

Conclusion: Insertion torque and RFA are valid, independent and incomparable methods of measuring primary stability. Is important for clinicians to define only one method of evaluation for each implant, preferentially RFA, because it allows repeated measurements to be taken during the course of long time evaluations.

Introduction

Dental implants have revolutionized the oral rehabilitation procedure in the last decades with high success rates and many possibilities for tooth replacement.[1] The osseointegration of the dental implants is one of the most important parameters evaluated in long term dental implant studies, and to achieve optimal osseointegration, primary stability is one of the most important factors.[2]

At the time of implant placement, the primary stability can be evaluated by insertion torque and RFA.[3] Several methods have been introduced to assess implant stability that can be compared with insertion torque.[4]

RFA (RFA) has become an important and widely used tool, because we can use it to assess implants at different time intervals, while insertion torque can only be measured at the time of surgery.[5] Moreover, RFA is a simple and noninvasive method.[6]

RFA is measured by means of the Osstell® device. This device, which uses transducers connected to the implant or prosthetic components, is available for various systems. The transducers (smartpegs) print a lateral force on the fixed components and the system shift is then measured. Thus, RFA measures the stiffness and deflection of the implant-bone complex.[7] The value obtained by Osstell® is automatically translated into an index called the Implant stability quotient (ISQ), ranging from 1 to 100 (with 100 being the highest stability), and also allows stability to be evaluated over time, and to identify the conditions of bone around the implant.[8,9]

Several clinical studies have demonstrated the reliability of this method for determining when to start loading on the implant,[10-14] and the value of ISQ 70 is considered the threshold for inserting the dental prosthesis and for immediate loading.[15]

In clinical practice many professionals consider an insertion torque of 45 Ncm for immediate loading, so that this is the value most commonly used and considered the safest and most therapeutic.[16]

The periotest is another method used to assess implant stability, however, this device is less used and popular than Osstell and the values cannot be compared.[17] Therefore, is better to understand the insertion torque and Osstell method, because these are the most commonly used methods.

Nevertheless, it is important to know whether the insertion torque and ISQ values are comparable and both methods can be used in clinics, especially because the ISQ has been widely used due to being applicable in different situations. The aim of this systematic review was to assess the supposed relationship between the insertion torque and RFA, investigating whether the two indexes provide similar assessments of primary implant stability for the same clinical case, thereby seeking to avoid discrepancies and facilitate communication among dentistry professionals.

METHODS

Protocol

The present systematic review was performed based on the PRISMA statement guidelines.[18] The protocol for this systematic review was registered in PROSPERO (CRD42017068374) and is available in full in the PROSPERO international prospective register of systematic reviews website (http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42017068374).

Focus question

Is there any relationship between implant stability measured by resonance frequency analysis and insertion torque?

Search strategy

The studies included in this systematic review were obtained through electronic searches of the PubMed/MEDLINE, Web of Science, SCOPUS, Cochrane Library electronic and Scielo databases. The keywords used were searched in Health Sciences Descriptors (DeCs), in Medical Subject Headings (Mesh) and in the published manuscripts of dental implants. The following terms were used: (osseointegration* OR dental implant* OR primary stability* OR implant stability* OR insertion torque*) AND (resonance frequency analysis* OR osstell* OR ISQ*)

A general search strategy was adapted to the characteristics of each database to identify studies of interest for this review. The databases were searched for articles and abstracts with no language restriction. A manual and gray literature search was performed by searches in dental implant-related journals. To identify the relevant journals to be hand-searched, the Cochrane Worldwide Hand-searching Program was checked (http://us.cochrane.org/master-list) This hand-searching included the following journals: British Journal of Oral and Maxillofacial Surgery; Clinical Implant Dentistry and Related Research; Clinical Oral Implants Research; European Journal of Oral Implantology; Implant Dentistry; International Journal of Oral and Maxillofacial Implants; International Journal of

Oral and Maxillofacial Surgery; International Journal of Periodontics and Restorative Dentistry; International Journal of Prosthodontics; Journal of Clinical Periodontology; Journal of Dental Research; Journal of Oral and Maxillofacial Surgery; Journal of Periodontology; Journal of Prosthetic Dentistry.

All the corresponding authors of the included clinical trials were contacted by e-mail to identify and obtain data from any unpublished or ongoing studies. The references contained in all studies and systematic reviews included were checked for additional trials. The reference list of the searches sought in the electronic databases was organized by EndNote® software (version 17.0).

Screening and Selection Process

For this systematic review, clinical trials (CTs) that met the inclusion criteria and dating from the inception of the respective databases through to January 2017 were selected. Inclusion was based on an analysis of the title and abstract of studies with regard to the eligibility criteria listed below.

Type of study: Clinical trials (either randomized or not) of any design that involved dental implants.

Participants: Patients were aged 18 years or older who had root-form dental implants.

Type of intervention: The interventions of interest were those reporting the resonance frequency measurement values by means of implant stability quotient (ISQ) and insertion torque.

Exclusion criteria: CTs not clearly meeting the inclusion criteria and those that did not report the ISQ values or insertion torque were excluded.

Outcomes: The primary outcome included ISQ and insertion torque. Secondary outcomes were dental implant stability, osseointegration and dental implant survival.

Review method and data extraction

The study selection process was performed by two reviewers (DWDdeO and FSL) in two phases. In the first phase, the two reviewers independently identified all relevant studies through electronic and other search methods based on the inclusion criteria applied to the titles and abstracts. For studies that appeared to meet the inclusion criteria or for which insufficient data was found in the title and abstract to make a clear decision, the full text was preselected. In the second phase, the preselected studies were analyzed by the same researchers to define whether the clinical trial met the inclusion criteria or not. When necessary, the authors of the clinical trials were contacted by e-mail to clarify issues related to the trials. Studies excluded in this or following stages were recorded along with the reasons for rejection. Clinical trials meeting the inclusion criteria were included in the final analysis and were submitted to data synthesis. Articles identified two or more times were considered only once.

The studies were analyzed and discussed by independent researchers, who conducted the systematic review. Disagreements were resolved by consensus among the two reviewers and a third reviewer (FOC). This procedure was applied at all steps. The reviewers were trained for each database prior the study.

Data were recorded qualitatively to allow comparisons among the studies selected. Each researcher qualitatively assessed the studies using an evaluation form. Data were collected on the following items: author; year of publication;

country; study design; characteristics of participants; ISQ value; insertion torque; follow up; implant brand; and results regarding the dental implants.

Quality assessment

The risk of bias was estimated for each selected clinical trial based on the Cochrane Handbook for Systematic Reviews of Interventions.[19] It was used A review manager software (RevMan, Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) was used to judge the following items: Random generation, allocation concealment, blinding of assessors, incomplete outcome data and other bias.

Meta-analysis and quality of evidence

In order to perform meta-analysis, the data retrieved from the selected studies were submitted to the Spearman correlation test. The mean insertion torque value and RFA of each group included in the respective studies were used.

Two investigators (DWDO and FSL) evaluated the quality of the evidence using GRADE (Grading of Recommendations Assessment, Development and Evaluation). Disagreements were resolved by discussion and consensus. Grade evaluates the quality of the evidence as high, moderate, low, and very low using five criteria: risk of bias, consistency, indirectness, imprecision, and publication bias. The relationship between RFA and IT was selected as outcome for inclusion in the GRADE evidence table. The quality of the evidence was presented using the GRADE PRO ® software (www.gradepro.org).

RESULTS

The electronic and hand search yielded 2017 relevant references. There were 770 duplicate records. In the first phase of study selection, 1233 publications were excluded after examining the title and abstract. The full texts of the remaining 14 articles were read. In this second stage, two articles were excluded, because the insertion torque was not shown.[20,21] Thus, a total of twelve studies met the selection criteria and were qualified for the qualitative analysis (Figure 1).[1, 22-32]

The studies included in this review were conducted in Brazil,[23,28] United States,[22,31,32] Italy,[24,27,29] Israel,[26] Australia,[25] and Spain.[30] One article was published in Hebrew,[26] and all the others in English.[1,22-25, 27-32] The participants of the reviewed studies were of both genders, and age ranged from 20 to 87 years. The main characteristics of the 12 articles are summarized in Table 1.

The mean ISQ value ranged from 58 (±5.5)[22] to 73.95 (±3.7).[29] The minimum and maximum insertion torque was 23.2 (±7.59)[32] and 52.00 (±9.23)[27] (Table 1).

Ten studies did not mention the blinding of assessors.[1,22-30] Eight studies presented incomplete outcome data.[1,22,25,27-29,31,32] The absence of sample calculation was considered risk of other bias in six reviewed studies.[1,23,24,26,31,32] Figures 2 and 3 represent the qualitative analysis of the included articles.

There was no statistically significant correlation between ISQ and insertion torque (r_s=0.366; p=0.079) (Figure 4).

The quality of the evidence was downgraded by risk of bias and indirectness; and the certainty of the evidence was low (Table 2).

DISCUSSION

Insertion torque and RFA are the techniques most used to assess primary implant stability.[33] Determination of the primary stability could be relevant to the prognosis of the dental implant.[6] There is a gap in the literature about the relationship between the above-mentioned two methods. The present systematic review showed no correlation between ISQ and insertion torque at the time of dental implant placement.

The primary stability is one of the important criteria for successful surgical dental implant placement.[34] Primary stability is defined as the absence of movement of an implant after surgical insertion and it is influenced by many factors such as bone density and quality, surgical technique and implant body geometry.[8] There are many methods for evaluating this. The methods most frequently used in clinical practice are the insertion torque and the RFA measured by means of the Osstell device.[27] In the present review, the selected articles came from 6 different countries, which demonstrated that this method of evaluation was utilized world-wide.

The studies reviewed herein showed a wide range of insertion torque values. Studies have suggested that high insertion torque values could be generated by aggressive implant insertion with increased thread depth that offers a close contact between the implant surface and the bone.[35] However, clinicians should be cautious about using excessive strain, because this compression on the press-fit regions could exceed the physiological limit and trigger bone resorption, leading to necrosis and dental implant failure.[36] Up to now, the amount of torque required to achieve sufficient primary stability is unknown.[37]

The disadvantage of insertion torque is that it is a measurement that can be performed at only one time; that is, at the time of implant placement, while RFA can be realized in all the phases of treatment with implants.[32] The Osstell® method can be used at the time of implant insertion, during the healing period, and when the dental prosthesis is in function.[5]

In the long term, studies that perform measurements in all the phases are required, so that the results can be compared. Therefore, either we perform the measurements with Osstell right from the initial phase, or it would be necessary to know whether there is any relationship between insertion torque and RFA.[32]

Irrespective of the implant dimensions and protocol used in the studies included in this review, there was no correlation between insertion torque and ISQ. This suggested that the two values should be evaluated independently, and they should be considered with caution when assessing the primary stability. A high torque does not mean a high ISQ and vice versa. Clinically, the insertion torque is still an easily obtainable and representative parameter for estimating the primary stability of dental implants.[24,38]

In clinical situations in which we wish to use the immediate loading technique, the primary stability is a fundamental requisite for doing so. We used the insertion torque value, that needed to be equal or higher than 40Ncm, or the ISQ value that needed to be equal or higher than 70. Some articles showed that insertion torque scores lower than 20Ncm were predictive of a higher failure rate for immediately loaded implants; and if RFA were considered, failure rates increased when the ISQ was lower than 55.[27,39,40] In the present study, there was no statistically significant correlation between ISQ and insertion torque, in agreement with the results shown in another clinically conducted study.[32] However, a study conducted with an edentulous mandible of a cadaver found a correlation between ITV and ISQ.[41] Therefore, further studies are necessary to determine whether the two measurement can be used, and whether these really are the limit values.

Is important to know whether the instruments used to perform the measurement were calibrated, and the operators been trained, because both the ratchet and the Osstell could generate false results if they were not working well. Moreover, in various studies the variation was very wide for the same sample.

Acil et al. 2016[35] postulated that immediately after implant insertion, relaxation would begin to take place. This can affect the ISQ measurements as well as bone contact measurements. Furthermore, it is well known that both ISQ measurements and bone contact measurements could also be affected by the visco-elastic behavior of the bone and possible concomitant relaxation, which takes place immediately after implant insertion.

The studies reviewed were judged as high risk of bias, leading to poor evidence. It seems that the studies did not follow the CONSORT guidelines that provide researchers with minimum criteria for reporting trials.[42] The CONSORT statement includes all parameters used in the qualitative analysis. The quality of clinical trials and research transparency can be improved by adopting the reporting guidelines.[43]

The main factor for poor quality of the studies was the absence of assessor blinding. A study may be conducted according to the highest possible standards, yet still have an important risk of bias.[19] In the studies reviewed it was impractical or difficult to blind the study personnel to torque and ISQ measurements, since these are taken by the operator at the time of implant insertion.

The authors could suggest that the studies identified had low evidence for identifying a relationship between RFA and IT. Important information on this issue is not available at present, considering that the eleven studies in this review had serious risk of bias. This may make it more difficult to generalize the findings about the measurements taken by ostell and torque. The overall certainty of evidence could be described as low, which meant that there was very little confidence in the outcome estimated, and further research would most probably have an important impact on the confidence in the estimate of effect.[44]

Further studies are necessary to compare and verify all the methods for evaluating implant stability and comparing the values. It would also be interesting if we could have correlated the values, and even if the measurements had been made by one method, we could have compared them with others performed at different times.

CONCLUSION

Insertion torque and RFA are valid, independent and incomparable methods of measuring primary stability. Is important for clinicians to define only one method of evaluation for each implant, preferentially RFA, because it allows repeated measurements to be taken during the course of long time evaluations.

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TABLES

Table 1. Characteristics of the reviewed studies.

STUDY	STUDY DESIGN	COUNTRY	PARTICIPANTS	TOTAL IMPLANTS	DROP-OUTS	INSERTION REGION	IMPLANT BRAND
ALGHAMDI ET AL 2016 [1]	Comparative study	Unclear	12 women, 17 men; 27-66yo	52	0	Maxilla and mandible	Straumann
BAREWAL ET AL 2012 [22]	RCT	United States	25 women, 15 men; 20 - 82yo	40	2	Poterior Maxilla and mandible	Astra Tech
DA CUNHA ET AL 2004 [23]	RCT	Brazil	8 women, 4 men; 24-46yo	24	NR	Maxillary first premolar and lateral incisor	Nobel Biocare
DEGIDI ET AL. 2013 [24]	RCT	Italy	20 women, 10 men; 26-73yo	96	0†	Posterior maxilla	Dentsply
HO ET AL. 2013 [25]	RCT	Australia	21 women, 11 men; 22-70yo	64	5	Posterior Maxilla and Mandible	Nobel Biocare
HORWITZ ET AL. 2003 [26]	RCT	Israel	12 women, 2 men; 46-71yo	53	0†	Maxilla and mandible	MIS Implants†
MALCHIOD ET AL. 2016[27]	RCT	Italy	16 women, 24 men; 35-75yo	40	0	Posterior region of both maxilla and mandible	Sybron Implant Solutions
OLIVEIRA ET AL. 2016 [28]	RCT	Brazil	23 subjects; 20-70yo	46	0	Posterior mandible	Conexão
SCHINCAGLIA ET AL. 2007 [29]	RCT	Italy	4 women, 6 men; 37-74yo	42	0	Posterior mandible	Nobel Biocare
TORROELLA-SARAU ET AL. 2015 [30]	RCT	Spain	10 subjects; age NR	40	NR	Mandible	MIS Implants Technologie ®
XING ET AL. 2015 [31]	RCT	United States	9 women, 7 men; 24-87yo	16	0	Maxilla	Biomet 3i
LEVIN ET AL. 2016 [32]	CT	United States	NR	13	0	Maxilla and mandible	Dentsply

YO: YEARS-OLD. RCT: RANDOMIZED CLINICAL TRIAL. CT: CLINICAL TRIAL. NR: NOT REPORTED. *VALUES CALCULATED BY THE AUTHORS OF THE PRESENT SYSTEMATIC REVIEW. †PERSONAL INFORMATION OBTAINED BY EMAIL CONTACT WITH THE CORRESPONDING AUTHOR OF THE INCLUDED ARTICLE.

Table 1 (contin.). Characteristics of the reviewed studies.

STUDY	GROUPS	IMPLANT DIMENSIONS	ISQ VALUE (MEAN (±SD))	TORQUE VALUE (MEAN (±SD))
ALGHAMDI ET AL. 2016 [1]	A. Standard drilling protocol B. Adapted bone drilling method	4.1 *x* 12 mm	A. 66.69 (±5.41) B. 68.58 (±4.81)	A. 34.62 (±5.82) B. 35.19 (±4.79)
BAREWAL ET AL 2012 [22]	A. Bone type 1 and 2 B. Bone type 3 C. Bone type 4	4.0 *x* 11 mm 4.0 *x* 13 mm	A. 72 (± 3.1) B. 70 (±4.2) C. 58 (±5.5)	A. 32.28 (±11.04) B. 16.61 (±7.78) C. 10.01 (±4.58)
DA CUNHA ET AL 2004 [23]	A. Brånemark standard implants B. TiUnite Mk III implants	3.75 *x* 13 mm	A. 69.00 (±2.80) B. 66.92 (±4.16)	A. 40.81 (±2.52) B. 33.4 0 (±6.57)
DEGIDI ET AL. 2013 [24]	A. 1-step surgery B. 2-step surgery	3.0, 3.4, 3.8, 4.5 *x* 9, 11, 13, 15	A. 65.25 (±4.45) B. 67.92 (±10.99)	A. 23.77 (±12.63) B. 26.48 (±20.80)
HO ET AL. 2013 [25]	A. NobelActive™ B. Brånemark implants	NR	A. 69.90 (±10.32) B. 72.28 (±10.16)	A. 47.1 B. 39.8
HORWITZ ET AL. 2003 [26]	A. Loaded non- submerged B. Submerged C. Non loaded non -submerged	3.3, 3.75, 4.2 x 10, 11.4, 13, 16 †	A. 63.30 (±2.85) B. 58.80 (±2.71) C. 67.20 (±3.54)	A. 40.10 (±1.8) B. 35.33 (±2.1) C. 46.00 (±4.0)
MALCHIOD ET AL. 2016 [27]	A. Immediate implant B. Delayed implant	3.3, 4.1 *x* 9, 11, 13	A. 61.90 (±9.99) B. 66.00 (±8.25)	A. 46.00 (±9.95) B. 52.00 (±9.23)
OLIVEIRA ET AL. 2016 [28]	A. Implant surface modified by acid etching B. Implant surface modified by anodizing	3.75 *x* 10 mm	A. 67.50 (±10.6) B. 65.60 (±9.8)	A. 45.00 (±10.6) B. 45.70 (±9.8)
SCHINCAGLIA ET AL. 2007 [29]	A. TiO implants B. Machined implants	4.0 † *x* 8.5, 10, 11.5, 13, 15 mm	A. 73.95 (±3.7) B. 73.04 (±4.5)	A. 44.00 (±9.40)* B. 45.91 (±7.96)*
TORROELLA-SARAU ET AL. 2015 [30]	A. Tapered implants B. Cylindrical implants	3.75, 4.2 *x* 11.5, 13 mm	A. 72.93 (±2.54) B. 72.36 (±5.80)	A. 51.50 (±3.60) B. 48.75 (±4.83)
XING ET AL. 2015 [31]	A. Conventional drilling B. Osteomes	4.0 *x* 10 mm	A. 65.9 (±13.8)* B. 63.5 (±12.16)*	A. 39.5 (±7.31)* B. 32.5 (±9.8)*

LEVIN ET AL. 2016 [32]	A. Immediate provisional implants	3.0 to 4.8 *x* 11 to 15 mm	A. 69.4 (±4.10)*	A. 23.2 (±7.59)*

yo: years-old. RCT: randomized clinical trial. CT: CLINICAL TRIAL. NR: not reported. *Values calculated by the authors of the present systematic review. †Personal information obtained by email contact with the corresponding author of the included article.

Table 2. Quality of the evidence (GRADE)

Quality assessment							№ of patients		Effect	Quality
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**RFA**	**IT**	**Absolute (95% CI)**	
Relationship between RFA and IT										
11	randomized trials	serious [a]	not serious	serious [b]	not serious	none	256	256	correlation **0.366** (0.048 lower to 0.84 higher)	⊕⊕◯◯ LOW

RFA: resonance frequency analysis. **IT:** insertion torque. **CI:** Confidence interval. [a] Lack of: sequence generation, allocation concealment, assessor blinding and incomplete data in at least one study. [b]Differences in age of the population (20 to 87 years, could lead to different relationship).

CONSIDERAÇÕES FINAIS

A Implantodontia é uma ciência ainda relativamente recente e em constante evolução e pesquisa na Odontologia. A longevidade das reabilitações implanto-suportadas e o sucesso em longo prazo da osseointegração ainda torna-se uma dúvida frequente dos pacientes e profissionais.

Atualmente, a análise de frequência de ressonância é o método que mais se destaca para essa avaliação de estabilidade, pois pode ser realizado no trans e pós-cirúrgico, próteses provisórias e definitivas, por ser simples, eficaz e não invasivo. Conhecer todos os princípios dessa análise e como ela se relaciona com os diversos fatores e nuances da implantodontia torna-se fundamental para que não tenhamos falsos resultados de estabilidade e conclusões decorrentes de medidas e comparações errôneas.

Nosso estudo sobre Análise de Frequência de Ressonância, concluiu que a altura do pilar teve um impacto significativo nas medidas de AFR. Quanto maior a altura do pilar transmucoso, menor o valor do quociente de estabilidade do implante. Na prática clínica, sugere-se que o ISQ medido no pilar não pode ser comparado com os valores medidos na plataforma do implante.

A revisão sistemática e meta-análise, apesar do baixo nível da evidência científica em decorrrência da heterogeneidade e de altos bias nos estudos, concluiu que o torque de inserção e a AFR podem ser métodos válidos, independentes e incomparáveis de medição da estabilidade primária dos implantes. Entretanto, é importante para os clínicos definir apenas um método de avaliação para cada implante, preferencialmente AFR, porque permite que medidas repetidas sejam tomadas durante avaliações de longo prazo.

Assim, nossos estudos recomendam que explorar e desenvolver a AFR como método de avaliação da estabilidade implantar deve ser uma busca ainda necessária das pesquisas científicas para melhor compreensão do comportamento dos implantes dentários, nos seus diversos momentos e situações na cavidade oral, bem como determinar um bom nível de estabilidade que consequentemente determinaria uma maior longevidade e funcionalidade dos implantes dentários.

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ANEXO 1

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Projeto: CAAE – 57216016.6.0000.5149

Interessado(a): Prof. Fernando de Oliveira Costa
Departamento de Clínica, Patologia e Cirurgia Odontológicas
Faculdade de Odontologia- UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 29 de junho de 2016, o projeto de pesquisa intitulado **" Correlação entre a estabilidade do implante nos componentes protéticos e na plataforma por meio da análise da frequência de ressonância: Um estudo transversal"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto através da Plataforma Brasil.

Profa. Dra. Telma Campos Medeiros Lorentz
Coordenadora do COEP-UFMG

Av. Pres. Antonio Carlos, 6627 – Unidade Administrativa II - 2º andar – Sala 2005 – Cep:31270-901 – BH-MG
Telefax: (031) 3409-4592 - e-mail: coep@prpq.ufmg.br

ANEXO 2

Termo de consentimento livre esclarecido

Gostaríamos de convidá-lo(a) para participar voluntariamente da nossa pesquisa, que tem como título "Correlação entre a estabilidade do implante nos componentes protéticos e na plataforma por meio da análise da frequência de ressonância: um estudo transversal". A pesquisa tem como objetivo determinar a correlação entre os valores do coeficiente de estabilidade dos implantes quando mensurados, por meio da frequência de ressonância, em diferentes alturas do componente protético e diretamente na plataforma do implante. Para a realização desta pesquisa, será necessário que pessoas com implantes dentários sejam submetidos a mensurações da análise de frequência de ressonância. Esta medida será realizada de maneira não invasiva e não trará qualquer prejuízo ao implante e à sua saúde. As avaliações serão feitas em um local reservado, de forma sigilosa e acompanhada pelo doutorando Frederico para assistência quando necessário. Garantimos que nenhum participante desta pesquisa terá seu nome revelado. Durante o procedimento, poderá gerar o mínimo de constrangimento do voluntário. Com esta pesquisa espera-se entender melhor a frequência de ressonância nos diferentes componentes do implante. Também gostaríamos de informar que você, como voluntário, pode desistir da participação na pesquisa a qualquer momento sem qualquer prejuízo ao tratamento que está sendo submetido nesta instituição. Os dados obtidos nesta pesquisa são confidenciais e serão publicados em trabalhos científicos. Você não vai pagar nada pelo que está sendo feito e não receberá remuneração por sua participação. Se tiver alguma dúvida relacionada à esta pesquisa, pode contatar Frederico (31-991053040/ fredlages@hotmail.com) ou Fernando (31-999540657/ focperio@uol.com.br). Para dúvidas éticas de pesquisa, entre em contato com o Comitê de Ética em Pesquisa da Universidade Federal de Minas Gerais (3409-4592), localizado à Av. Ant. Carlos, 6627, Unid. Administrativa II, sala 2005, Campus Pampulha, Belo Horizonte. Você também receberá uma via deste termo.

Eu, ____, declaro que fui informado (a) sobre a pesquisa e concordo em participar voluntariamente deste estudo.

Belo Horizonte, _________de ______________________________de __________

____

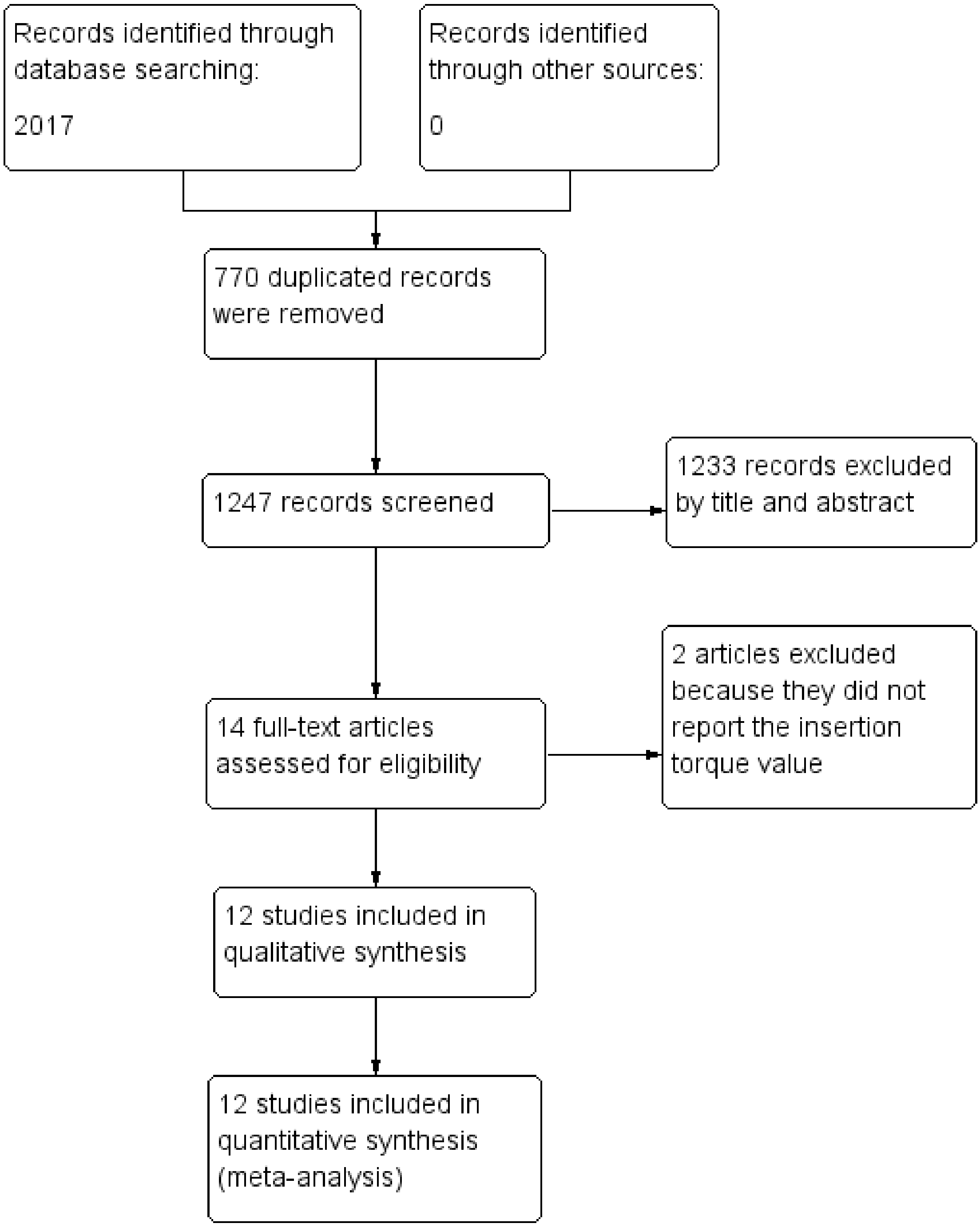
Assinatura do participante

__________________________ ______ ________________________

Aluno: Frederico Santos Lages Orientador: Fernando de Oliveira Costa

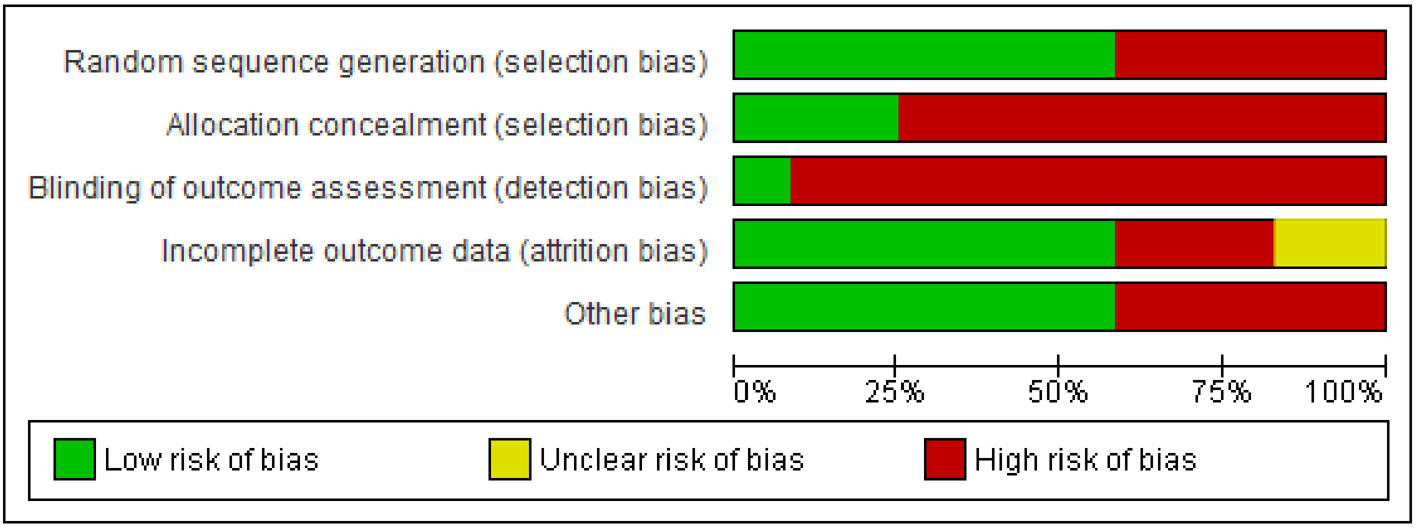
ANEXO 3

Figure 1. PRISMA Flowchart of selection process of the systematic review.



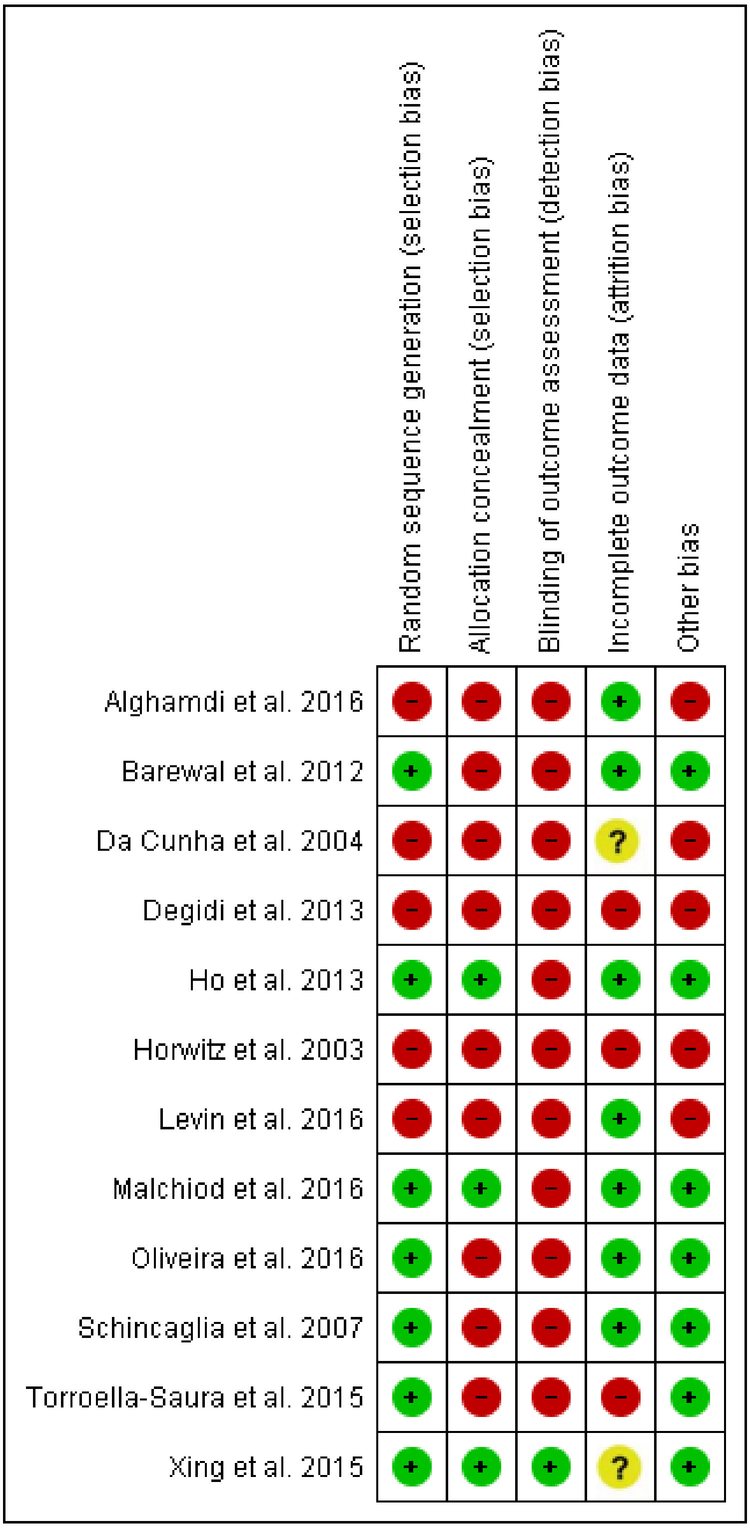
ANEXO 4

Figure 2. Table of risk of bias of included studies.



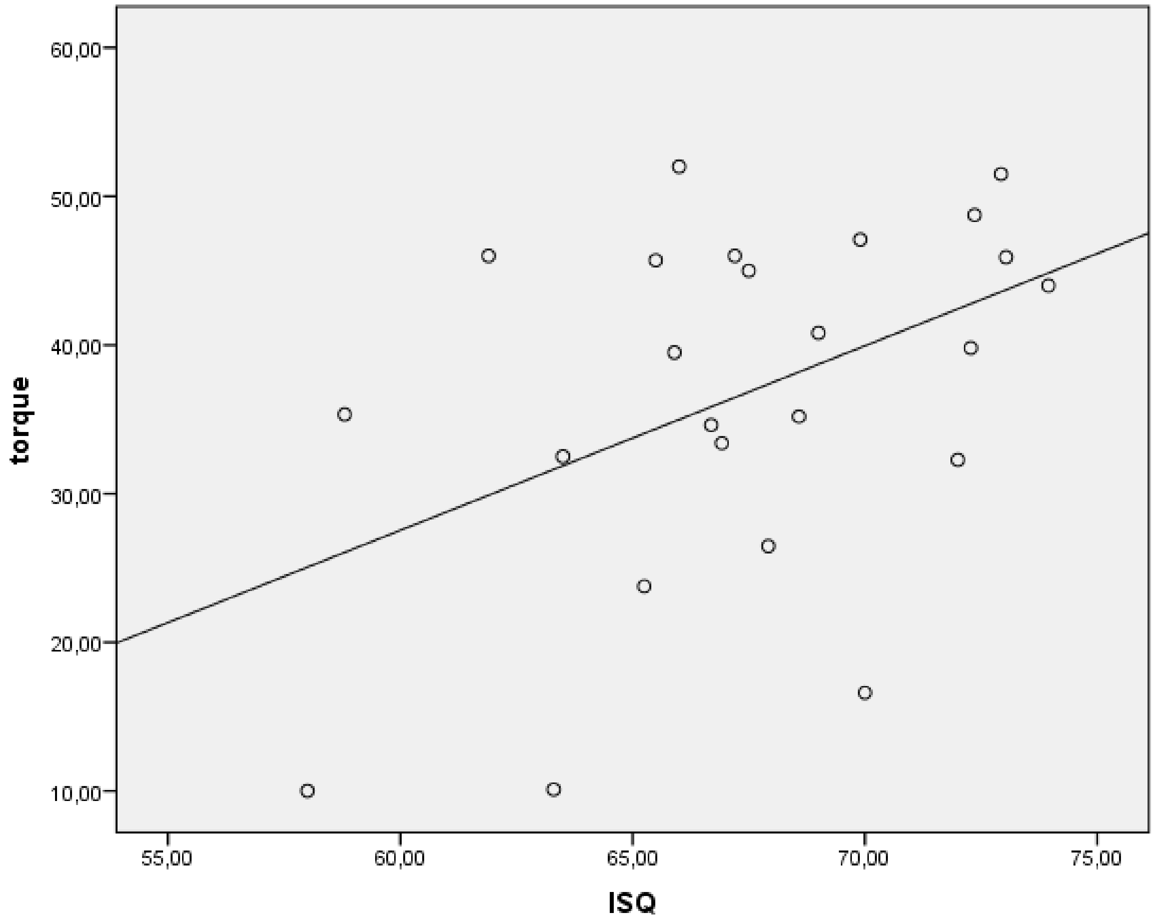
ANEXO 5

Figure 3. Quality assessment of clinical trials included.



ANEXO 6

Figure 4. Correlation between ISQ and torque.



ANEXO 7

Carta de submissão do artigo científico 2

Clinical Implant Dentistry and Related Research

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Author

Submission Confirmation

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Thank you for your submission

Submitted to
Clinical Implant Dentistry and Related Research

Manuscript ID
CID-17-216

Title
Relationship between Implant Stability Measurements Obtained by Insertion Torque and Resonance Frequency Analysis: A Systematic Review and Meta-analysis

Authors
Lages, Frederico
Douglas-de-Oliveira, Dhelfeson
Costa, Fernando

Date Submitted
13-Aug-2017

Author Dashboard

PRODUÇÃO INTELECTUAL DURANTE O DOUTORADO

Trabalhos apresentados em eventos técnico-científicos:

1. SOARES, A. M.; LANZA, C. R. M.; AZEVEDO, M. N.; NAVES, M. C ; PAIVA, M. F.; LAGES, F. S.; QUEIROZ, M. M.; AMARAL, T. M. P.; LANZA, L. D.; ABDO, E. N.; MESQUITA, R. A.; BARREIROS, I. D.; MORENO, A. . PRÓTESE BUCOMAXILOFACIAL: A ODONTOLOGIA QUE UNE ARTE, ESTÉTICA E FUNÇÃO NA REABILITAÇÃO DE PACIENTES PORTADORES DE DEFEITOS MAXILOFACIAIS.. 2016. (Apresentação de Trabalho/Congresso).

2. LAGES, F. S.. Zircônias monolíticas: Soluções para reabilitações unitárias e múltiplas. 2016. (Apresentação de Trabalho/Conferência ou palestra).

3. LAGES, F. S.. O uso consciente da tecnologia na reabilitação oral. 2015. (Apresentação de Trabalho/Conferência ou palestra).

4. LAGES, F. S.. Aplicações da Tecnologia e dos Sistemas CAD/CAM na Odontologia Moderna. 2014. (Apresentação de Trabalho/Conferência ou palestra)

Artigos publicados:

1. LAGES F.S.; WILLYA DOUGLAS-DE-OLIVEIRA D.; IBELLI G.S.; ASSAF F.; QUEIROZ T.P.; COSTA F.O.. Relationship between implant stability on the abutment and platform level by means of resonance frequency analysis: A cross-sectional study. PLoS One. 2017 Jul 24;12(7):e0181873.

2. OLIVEIRA, D. W. D.; LAGES, F. S.; GUIMARAES, R. C.; PEREIRA, T. S.; BOTELHO, A. M.; GLORIA, J. C. R.; TAVANO, K. T. A.; GONCALVES, P. F.; FLECHA, O. D.. Do TMJ Symptoms Improve And Last Across Time After Treatment With Red(660nm) And Infrared(790nm) Low Level Laser Treatment (LLLT)? A Randomized Clinical Trial.. Cranio. Journal of Craniomandibular Practice, 2017.

3. de MOLON, R. S.; LAGES, F. S.; RIVERA, C. P.; FALONI, A. P. S.; MARGONAR, R.; QUEIROZ, T. P.. Evaluation of Short and Regular Implants After Prosthesis Placement in the Mandible. A Non Randomized Controlled Clinical Trial.. The Journal of Contemporary Dental Practice, 2017.

4. VIEIRA, T. R.; OLIVEIRA, D. W. D.; LAGES, F. S.; COTA, L. O. M.; COSTA, F. O.; ZENOBIO, E. G.. Influence of periodontal parameters on root coverage: A longitudinal study. Journal of the International Academy of Periodontology, 2017.

5. VIEIRA, T. R.; OLIVEIRA, D. W. D.; LAGES, F. S.; SOARES, R. V.; HORTA, M. C. R.; ZENOBIO, E. G.. Effect of Periodontal Parameters on Root Coverage.. Journal of the International Academy of Periodontology, v. 18, p. 86-93, 2016.

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7. OLIVEIRA, D. W. D.; LAGES, F. S.; LANZA, L. A.; GOMES, A. M.; QUEIROZ, T. P.; COSTA, F. O.. Dental Implants With Immediate Loading Using Insertion Torque of 30 Ncm. Implant Dentistry (Print), v. 25, p. 675-683, 2016.

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11. LAGES, F. S.; RIVERA, C. P.; ARAUJO, D. C. E.; OLIVEIRA, D. W. D. . Protetor bucal para esportistas: relato de caso clínico. Revista da Faculdade de Odontologia de Lins, v. 24, p. 32-36, 2014.