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

RAFAEL ZETEHAKU ARAUJO

Modifying Mandibular Kennedy Class I to Class III by using Implant-Assisted Removable Partial Dentures - A 3-year clinical trial with Masticatory Performance and Quality of Life Evaluation

Tese apresentada à Faculdade de Odontologia da Universidade Federal de Uberlândia, como requisito parcial para obtenção do Título de Doutor em Odontologia na Área de Concentração de Implantodontia e Prótese Sobre Implante

RAFAEL ZETEHAKU ARAUJO

Uberlândia, Julho de 2022

Modifying Mandibular Kennedy Class I to Class III by using Implant-Assisted Removable Partial Dentures - A 3-year clinical trial with Masticatory Performance and Quality of Life Evaluation

Tese apresentada à Faculdade de Odontologia da Universidade Federal de Uberlândia, como requisito parcial para obtenção do Título de Doutor em Odontologia na Área de concentração de Implantodontia e Prótese sobre implante.

Banca Examinadora:
Orientador: Prof. Dr. Flávio Domingues das Neves, UFU
Prof. Dr. Flávio Domingues das Neves, UFU
Prof. Dr. Raphael Freitas de Souza, McGill University, Candaá
Prof. Dra. Gabriella Mercedes Peñarrieta Juanito, ILAPEO
Prof. Dr. Guilherme José Pimentel Lopes de Oliveira, UFU
Prof. Dr. Darceny Zanetta Barbosa, UFU

Suplentes
Prof. Dra. Germana De Villa Camargos, UFU
Prof. Dra. Brunna Mota Ferrairo, UENP

Uberlândia, Julho de 2022

Ficha Catalográfica Online do Sistema de Bibliotecas da UFU
com dados informados pelo(a) próprio(a) autor(a).

A663 Araujo, Rafael Zetehaku, 1983-
2022 Prótese parcial removível mandibular assistida por implante – Modificação da Classe I para Classe III de Kennedy [recurso eletrônico] : Estudo clínico prospectivo de 3 anos com avaliação da performance mastigatória e qualidade de vida / Rafael Zetehaku Araujo. - 2022.

Orientadora: Flávio das Neves.
Coorientadora: Karla Zancopé.
Tese (Doutorado) - Universidade Federal de Uberlândia, Pós-graduação em Odontologia.
Modo de acesso: Internet.
Disponível em: http://doi.org/10.14393/ufu.te.2022.317
Inclui bibliografia.

1. Odontologia. I. Neves, Flávio das,1965-, (Orient.). II. Zancopé, Karla ,1984-, (Coorient.). III. Universidade Federal de Uberlândia. Pós-graduação em Odontologia. IV. Título.

CDU: 616.314

Bibliotecários responsáveis pela estrutura de acordo com o AACR2:
Gizele Cristine Nunes do Couto - CRB6/2091
Nelson Marcos Ferreira - CRB6/3074

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

ATA DE DEFESA - PÓS-GRADUAÇÃO

Programa de Pós-Graduação em:	Odontologia				
Defesa de:	Tese Doutorado, nº 83, PPGODONTO				
Data:	Vinte e Quatro de Agosto de Dois Mil e Vinte e Dois	Hora de início:	08:00	Hora de encerramento:	12:44
Matrícula do Discente:	11813ODO013				
Nome do Discente:	Rafael Zetehaku Araújo				
Título do Trabalho:	Prótese parcial removível mandibular assistida por implante – Modificação da Classe I para Classe III de Kennedy – Estudo clínico prospectivo de 3 anos com avaliação da performance mastigatória e qualidade de vida				
Área de concentração:	Clínica Odontológica Integrada				
Linha de pesquisa:	Implantodontia e Prótese sobre Implante				
Projeto de Pesquisa de vinculação:	Implantodontia e Prótese sobre Implante				

Reuniu-se em Web Conferência pela plataforma Zoom, em conformidade com a PORTARIA Nº 36, DE 19 DE MARÇO DE 2020 da COORDENAÇÃO DE APERFEIÇOAMENTO DE PESSOAL DE NÍVEL SUPERIOR - CAPES, pela Universidade Federal de Uberlândia, a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em Odontologia, assim composta: Professores Doutores: Guilherme José Pimentel Lopes de Oliveira (UFU); Darceny Zanetta Barbosa (UFU); Raphael Freitas de Souza (MCGILL UNIVERSITY); Brunna Mota Ferrairo (UENP); Flávio Domingues das Neves (UFU) orientador(a) do(a) candidato(a).

Iniciando os trabalhos o(a) presidente da mesa, Dr(a). 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 arguição e resposta foram conforme as normas do Programa.

A seguir o senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos(às) examinadores(as), que passaram a arguir o(a) candidato(a). Ultimada a arguição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu o resultado final, considerando o(a) candidato(a):

Aprovado(a).

Esta defesa faz 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. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Documento assinado eletronicamente por **Flavio Domingues das Neves**, **Professor(a) do Magistério Superior**, em 02/09/2022, às 10:18, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Darceny Zanetta Barbosa**, **Professor(a) do Magistério Superior**, em 02/09/2022, às 10:46, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Guilherme José Pimentel Lopes de Oliveira**, **Professor(a) do Magistério Superior**, em 02/09/2022, às 10:57, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Raphael Freitas de Souza**, **Usuário Externo**, em 02/09/2022, às 12:24, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

Documento assinado eletronicamente por **Brunna Mota Ferrairo**, **Usuário Externo**, em 05/09/2022, às 11:02, conforme horário oficial de Brasília, com fundamento no art. 6º, § 1º, do Decreto nº 8.539, de 8 de outubro de 2015.

A autenticidade deste documento pode ser conferida no site https://www.sei.ufu.br/sei/controlador_externo.php?acao=documento_conferir&id_orgao_acesso_externo=0, informando o código verificador **3885467** e o código CRC **13FBB64C**.

Referência: Processo nº 23117.057267/2022-81 SEI nº 3885467

DEDICATÓRIA

À *Deus em primeiro lugar*,

Por me proporcionar tanto. Tentarei retribuir tantas oportunidades e bençãos o quanto e sempre que eu puder, e ainda assim sentirei que não será o suficiente para agradecer tamanha gratidão que eu tenho por tudo o que vem ocorrendo em minha vida desde sempre.

A TODA minha família

Sempre ao meu lado, evoluímos, brincamos, sofremos, choramos e sorrimos juntos. No final, tudo sempre dá certo e somos muito felizes. Nada tem valor ou graça sem vocês. E as minhas filhas, Ana Maria e Elisa, vocês são a minha força maior. Estarei aqui para vocês todos os dias das nossas vidas.

Ao meu orientador Professor Flávio

Um professor na exata concepção da palavra. Simples, inteligente, honrado, humilde e direto. Respeita as pessoas e principalmente seus pacientes. Mantém o equilíbrio e a postura profissional, com ética e responsabilidade. Além de aprender muito “tecnicamente” com o senhor na Implantodontia e na Odontologia como um todo, meu aprendizado como ser humano foi muito maior. E isso nenhum doutorado no mundo prometia e eu “ganhei”. Portanto, obrigado pelo grande exemplo que o senhor é, ao qual busco seguir e tentarei ensinar os meus alunos a se comportar e enxergar a Odontologia de forma semelhante.

AGRADECIMENTOS ESPECIAIS

Agradeço a minha co-orientadora profa. Karla Zancopé, a todos os colegas do grupo de pesquisa NEPRO que sempre me acolheram com muito carinho e ajuda desde quando iniciou o doutorado até os dias atuais, mas em especial ao colega nos trabalhos Rodrigo Moreira, um agradecimento especial ao meu grande amigo/irmão Felipe Peres e a Larissa, ao qual me deram todo o suporte necessário em Uberlândia nesses quase 5 anos, fazendo com que eu me sentisse em casa sempre que eu estivesse nessa linda cidade, e ao meu amigo pessoal e grande professor que ajudou muito na reta final dos trabalhos Gefter Correa.

A minha equipe da pós-graduação do NEEO e da clínica TRIALIS, que entenderam minha ausência durante muitas semanas e nesse último ano de 2022, e sempre se dedicaram arduamente pela nossa clínica e nossa escola de pós-graduação. Muito obrigado! E ao meu irmão, sócio e parça de triatlhon João Leahy, que segura as pontas na minha ausência do doutorado. Confiança e respeito é a base de qualquer relação duradoura e saudável.

Aos professores da FOUFU (toda a equipe docente sem exceção), que me fizeram fazer tantas e tantas (e tantas) disciplinas extras apenas para estar mais próximos a vocês e aprender um pouco mais. A dedicação de vocês a este programa de pós-graduação é inspiradora e eu tenho muito orgulho em dizer que diz meu doutorado na Universidade Federal de Uberlândia. Vale a menção especial a alguns dos professores que eu estive mais próximo nessas Disciplinas e tanto aprendi na Odontologia, mas principalmente, na postura e atuação frente à missão de ser professor. Gratidão aos professores Carlos Soares, Priscila Barbosa, Guilherme Oliveira, Paulo Simamoto e Paulo Vinícius.

A toda equipe de apoio da UFU e da PPGO, **Laís, Brenda e Graça,** vocês tornam o nosso processo muito mais fácil, sempre dispostas a ajudar no que for preciso, além de excelentes profissionais.

E a todas as pessoas que, de alguma forma, contribuíram para que essa etapa fosse vencida!

EPÍGRAFE

“Veja! Não diga que a canção Está perdida
Tenha fé em Deus Tenha fé na vida
Tente outra vez!

Beba! (Beba!) Pois a água viva Ainda tá na fonte
Você tem dois pés Para cruzar a ponte
Nada acabou! Não! Não! Não!

Tente! Levante sua mão sedenta E recomece a andar
Não pense Que a cabeça aguenta Se você parar
Não! Não! Não!

Há uma voz que canta, Uma voz que dança, Uma voz que gira, Bailando no ar

Queira! (Queira!) Basta ser sincero E desejar profundo
Você será capaz De sacudir o mundo
Vai! Tente outra vez!

Tente! (Tente!) E não diga Que a vitória está perdida
Se é de batalhas Que se vive a vida
Tente outra vez!”

Raul Seixas

SUMÁRIO

RESUMO

RESUMO

O número de pacientes com múltiplo edentulismo ainda é alto e com a tendencia ao envelhecimento populacional, esse número tem aumentado. Em alguns países, esse cenário é ainda pior, em virtude de fatores sociais, culturais e econômicos. Especialmente em região posterior de mandíbula, a perda dentária leva a uma alteração no sistema estomatognático afetando sensorialmente e aspectos motores afetando a mastigação, alimentação e qualidade de vida destes pacientes. Uma das formas de reabilitação oral, especialmente em países economicamente desfavoráveis, ainda é a utilização de Prótese parcial removível. Em região mandibular, para pacientes Classe I de Kennedy, que correspondem a 60% dos portadores desse tipo de prótese, esse tratamento é associado com doença cariosa e periodontal do dente pilar, baixa retenção da prótese, dor e compressão da mucosa ao mastigar e insatisfação do paciente, que muitas vezes abandona o tratamento. Como formas alternativas, surgem os implantes dentários, mas muitas vezes, no caso de mandíbulas atróficas, podem ser necessários tratamentos reconstitutivos, aumentando a possiblidade de complicações e a complexidade do tratamento, sem contar no aumento total do tempo de tratamento, custos e morbidade associada. No caso de pacientes mais idosos, além do fato de doenças sistêmicas estarem presentes e serem limitantes a essas reconstruções, o próprio paciente pode não querer escolher tratamentos reconstrutivos ou não ter condições financeiras para tal. Uma opção pode ser o uso de implantes curtos para se evitar as reconstruções. O tratamento com apoio posterior em um implante dentário transformando o paciente Classe I em Classe III de Kennedy já foi citado na literatura, mas quando este estudo foi iniciado, nenhum estudo com implantes curtos e cicatrizadores havia sido publicado na literatura. Sendo assim, esta tese de doutorado possuí 4 objetivos específicos: **Objetivo especifico 1:** O objetivo do presente estudo foi avaliar a performance mastigatória através da habilidade de mistura e força máxima de mordida, a qualidade de vida e o dente pilar da prótese removível inferior (PPRI), após a instalação de um implante dentário curto Neodent WS e um cicatrizador e o apoio da PPRI sobre este implante/cicatrizador. **Objetivo especifico 2:** Revisar a literatura criticamente em relação aos métodos de performance mastigatória disponíveis correlacionado os mesmos com as suas formas de avaliação e obtenção de resultados, e secundariamente, avaliar se é possível sugerir um método de avaliação de performance mastigatória de acordo com o perfil do paciente ou o tipo de tratamento instituído. **Objetivo especifico 3:** Apresentar uma série de casos clínicos de 5 pacientes consecutivos e uma rápida avaliação de força de mordida e habilidade de mistura e questionário de satisfação, com o objetivo de propagar

este tipo de tratamento e conhecimento, além de servir como um piloto para os nossos primeiros resultados da pesquisa. **Objetivo especifico 4:** Em parceria com a programa de doutorado da USP-Ribeirão Preto, estudar o desempenho de implantes curtos Neodent WS para reabilitações unitárias e acompanhar os resultados clínicos e radiográficos desses implantes correlacionando-os com as proporções de tamanho de coroa e proporção implante/prótese para coroas unitárias, hipotetizando que os mesmos teriam desempenho semelhante a implantes considerados padrão/normais na literatura.

Palavras chaves: implantes curtos, implantes dentários, atrofia óssea, performance mastigatória, qualidade de vida.

ABSTRACT

ABSTRACT

The number of patients with multiple edentulism continue to grow and with the population aging trend, this number has increased. In some countries, this scenario is even worse, due to social, cultural and economic factors. Especially in the posterior region of the mandible, tooth loss leads to a change in the stomatognathic system, affecting sensory and motor aspects, affecting chewing, eating and quality of life of these patients. One of the forms of oral rehabilitation, especially in economically disadvantaged countries, is still the use of removable partial dentures. In the mandibular region, for Kennedy Class I patients, who correspond to 60% of the patients with this type of prosthesis, this treatment is associated with carious and periodontal disease of the abutment tooth, low retention of the prosthesis, pain and mucosal compression when chewing, and dissatisfaction of the patient, who often abandons the treatment. As alternative forms, dental implants appear, but often, in the case of atrophic mandibles, reconstructive bone surgeries may be necessary, increasing the possibility of complications and the complexity of the treatment, not to mention the total increase in treatment time, costs and associated morbidity. In the case of older patients, in addition to the fact that systemic diseases are present and limit these reconstructions, the patient himself may not want to choose reconstructive treatments or may not have the financial means to do so. One option may be the use of short implants to avoid reconstructions. Treatment with posterior support on a dental implant transforming the Class I patient into Kennedy Class III has already been mentioned in the literature, but when this study was started, no studies with short implants and healing had been published in the literature. Therefore, this doctoral thesis has 4 specific objectives: **Specific objective 1:** The objective of the present study was to evaluate the masticatory performance through the mixing ability and maximum bite force, the quality of life and the abutment tooth of the lower removable prosthesis, after the placement Neodent WS short dental implant and a screw healer and the support of the prosthesis. **Specific objective 2:** To review the literature critically in relation to the available masticatory performance methods, correlating them with their forms of evaluation and obtaining results, and secondarily, to evaluate if it is possible to suggest a method of masticatory performance evaluation according to the profile of the patient or the type of treatment instituted. **Specific objective 3:** To present a series of clinical cases of 5 consecutive patients and a quick assessment of bite force and mixing ability and satisfaction questionnaire. Our goal with this work is to propagate this type of treatment and knowledge, in addition to serving as a pilot for our first search results. **Specific objective 4:** In partnership with the doctoral program at USP-Ribeirão Preto, to study the performance of Neodent WS short implants for single-unit rehabilitations and to monitor the clinical and radiographic results of these implants, correlating them with the proportions of crown size and implant/prosthesis proportion. We hypothesized that they would have similar performance to implants considered

standard/normal in the literature.

Keywords: short implants, dental implants, bone atrophy, masticatory performance, quality of life.

INTRODUÇÃO E REFERENCIAL TEÓRICO

1. INTRODUÇÃO E REFERENCIAL TEÓRICO

Na Odontologia, as Próteses Parciais Removíveis são amplamente utilizadas para reabilitar, principalmente, pacientes Classe I de Kennedy, ou seja, pacientes que possuem arco posterior desdentado bilateral. Esse tratamento vem se tornando cada vez menos comum, devido aos tratamentos relacionados à Implantodontia (Christensen, 2006).

A reabilitação de perdas dentárias por meio de próteses parciais fixas implanto-suportadas é atualmente uma realidade clínica inquestionável, uma vez que a sobrevivência dos implantes dentais, nestas condições, tornou-se um fato bem documentado e com altos índices de sucesso (Branemark et al., 1977; Adell et al., 1981; Attard & Zarb, 2003). Entretanto, ainda existem pacientes que não possuem condições sistêmicas e/ou anatômicas, e em muitos casos especialmente em países em desenvolvimento, condições financeiras de realizar uma reabilitação completa com implantes. A esses pacientes, as próteses parciais removíveis continuam sendo um dos principais tratamentos realizados.

Um dos principais objetivos de um tratamento odontológico é alcançar, por meio da restauração dos dentes naturais e/ou da substituição dos dentes perdidos, uma função mastigatória aceitável (Boretti et al., 1995; Prado et al., 2006; Oliveira et al., 2008; Mendonca et al., 2009; Borges et al., 2011). A avaliação desta função é um importante critério de controle de qualidade dos tratamentos realizados.

As próteses parciais removíveis de extremidade livre (PPREL), pelo fato de não apresentarem suporte dental distal e haver uma grande diferença entre a resiliência da fibromucosa e o movimento de intrusão do dente no alvéolo, são as que apresentam as maiores dificuldades quanto à sua resolução. Além disso, os portadores de PPREL sentem algum grau de desconforto e insatisfação geral com o tratamento, queixando-se principalmente de instabilidade das próteses e dificuldades mastigatórias (Witter et al., 1990; Borges et al., 2011; Gonçalves et al., 2013.).

Os termos performance e eficiência mastigatória, considerados por muitos autores como sinônimos, diferem entre si pelo método utilizado na obtenção de seus índices. O índice de eficiência mastigatória é obtido investigando o número de ciclos mastigatórios necessários para redução do tamanho das partículas do alimento-teste a um determinado tamanho, geralmente à metade do seu tamanho inicial. Para tanto, o alimento-teste é mastigado por diferentes números de ciclos mastigatórios, ou até que se forme um bolus alimentar apropriado para a deglutição, quando é denominado teste de limiar de deglutição. Já o índice de performance mastigatória é obtido pela análise da distribuição do tamanho das partículas do alimento-teste mastigado durante um número

determinado de ciclos mastigatórios (Mendonca et al., 2009; Borges et al., 2011; Silva et al., 2011).

Trabalhos recentes demonstram que a utilização de próteses parciais removíveis classe I de Kennedy possuem uma pior performance mastigatória quando comparados a outros tipos de tratamento, como reabilitações com implantes dentários (Borges et al., 2011, Campos et a., 2013, Gonçalves et al.,2014). Diversos estudos apontaram para a melhora da performance mastigatória progressiva ao comparar tratamentos que possuem maior estabilidade comparativamente a reabilitações menos estáveis, como por exemplo próteses removíveis com overdenture ou prótese fixa (Wismeijer et al., 2011, Van der Bilt, 2011, Prado et al. 2015).

Na tentativa de resolver a diferença na resiliência entre a fibromucosa e os elementos dentais, vários autores sugeriram a colocação de implantes distais ao espaço edêndulo, para que o implante sirva como apoio a essa Prótese Parcial. Antes que a sela da prótese intrua no tecido mole, encontra o dispositivo associado ao implante como anteparo (Mitrani et al., 2003; Kuzmanovic et al., 2004; Liu et al., 2011; Wismeijer et al., 2011, Campos et a., 2013, Gonçalves et al.,2014). Espera-se com esse tipo de tratamento, que exista maior estabilidade da prótese removível, gerando melhor conforto do paciente (Ohkubo et al., 2008; Grossmann et al., 2009; Liu et al., 2011). A utilização de apenas dois implantes pode diminuir significativamente os custos associados para esses pacientes, tornando a solução mais acessível a parcela da população que realmente precisa do tratamento em virtude de perdas dentárias e restrições financeiras (Mitrani et al., 2003; Ohkubo et al., 2008; Grossmann et al., 2009).

Trabalhos presentes na literatura realizaram esse tipo de tratamento com a instalação do implante dentário distal associado a dispositivos do tipo o’ring, o que não modifica realmente a classificação de Kennedy da arcada dental, não diminui a sobrecarga aos dentes pilares com pouco suporte ósseo conforme demonstrado em estudos laboratoriais (Cunha et al., 2011; Verri et al., 2011). A avaliação da modificação da Classe I de Kennedy para Classe III com a instalação de próteses fixas sobre implante, só foi demonstrada em um estudo, e este não avaliou o desempenho a curto ou longo prazo do dente pilar retentivo da prótese removível, tendo avaliado apenas o implante distal instalado (Gonçalves et al., 2013; Campos et al., 2013; Gonçalves et al. 2014).

OBJETIVOS

2. OBJETIVOS

Objetivo Geral

O objetivo deste trabalho é avaliar a performance mastigatória através da habilidade de mistura e da força máxima de mordida de pacientes classe I de Kennedy, antes e após a instalação de dois implantes distais transformando-os em classe III de Kennedy. Será ainda avaliado clinicamente por profundidade de sondagem e radiograficamente a sobrevida e desempenho de dentes pilares e dos referidos implantes na situação descrita. O intuito é demonstrar a viabilidade de uma técnica que melhore as condições gerais do tratamento com uma redução dos custos totais associados a uma reabilitação completa com implantes dentários. A satisfação geral do tratamento através de questionário de qualidade de vida OHIP-19, validado para população edêntula brasileira será aplicado para se avaliar o impacto do tratamento. A literatura pertinente sobre performance mastigatória será revisada com o intuito de buscar uma padronização ou protocolo em relação a uma possível melhor ou mais vantajosa forma de avaliação dentre as diversas disponíveis, procurando apontar se há hoje método mais eficiente, reproduível e confiável para utilização. O alimento teste goma de mascar, será avaliado em relação a sua dureza e estabilidade de cor em diferentes condições de temperatura e armazenamento, assim como os resultados obtidos de software próprio para avaliação da eficiência mastigatória. Em paralelo, um trabalho a respeito do desempenho clínico dos mesmos implantes curtos Neodent WS, será realizado em parceria com o programa de pós-graduação da Faculdade de Odontologia da USP-Ribeirão Preto.

Objetivos específicos

Objetivo específico 1

Capítulo 1 - **Modifying Mandibular Kennedy Class I to Class III by using Implant-Assisted Removable Partial Dentures - A 3-year clinical trial with Masticatory Performance and Quality of Life Evaluation**

O objetivo do presente estudo foi avaliar a performance mastigatória através da habilidade de mistura e força máxima de mordida, a qualidade de vida e o dente pilar da prótese removível inferior (PPRI), após a instalação de um implante dentário curto Neodent WS e um cicatrizador e o apoio da PPRI sobre este implante/cicatrizador.

Objetivo específico 2

Capítulo 2 - **Masticatory function evaluation methods: Critical analysis of selected literature.**

Revisar a literatura criticamente em relação aos métodos de performance mastigatória disponíveis correlacionado os mesmos com as suas formas de avaliação e obtenção de resultados, e secundariamente, avaliar se é possível sugerir um método de avaliação de performance mastigatória de acordo com o perfil do paciente ou o tipo de tratamento instituído.

Objetivo específico 3

Capítulo 3 – **Mandibular implant-assisted removable partial denture - Kennedy class I to class III modification – Case series with masticatory performance and satisfaction evaluation**

Apresentar uma série de casos clínicos de 5 pacientes consecutivos e uma rápida

avaliação de força de mordida e habilidade de mistura e questionário de satisfação, com o objetivo de propagar este tipo de tratamento e conhecimento, além de servir como um piloto para os nossos primeiros resultados da pesquisa.

Objetivo específico 4

Capítulo 4 – **Short dental implants in posterior single crowns: A five-year follow-up of a trial study**

Em parceria com a programa de doutorado da USP-Ribeirão Preto, estudar o desempenho de implantes curtos Neodent WS para reabilitações unitárias e acompanhar os resultados clínicos e radiográficos desses implantes correlacionando-os com as proporções de tamanho de coroa e proporção implante/prótese para coroas unitárias, hipotetizando que os mesmos teriam desempenho semelhante a implantes considerados padrão/normais na literatura.

CAPÍTULOS

3. CAPÍTULOS

3.1 CAPÍTULO 1

Artigo submetido na International Journal of Oral Maxillofacial Implants (IJOMI, Qualis A2 em Odontologia) em 23 / 07 / 2022 – *Aguardando parecer inicial dos revisores*

Modifying Mandibular Kennedy Class I to Class III by using Implant-Assisted Removable Partial Dentures - A 3-year clinical trial with Masticatory Performance and Quality of Life Evaluation

Rafael Zetehaku Araujo DDS, MS [a]
Karla Zancopé DDS, MS, PhD [b]
Rodrigo Silva Moreira DDS [c]
Gefter Thiago Batista Correa DDS, MS, PhD [d]
Flávio Domingues das Neves DDS, MS, PhD [e]

[a] Doctorate Student of Oral Implantology. School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

[b] Professor, Department of Occlusion, Prosthesis and Dental Material, School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

[c] Master Degree student of Oral Implantology. School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

[d] Professor, Department of Surgery and Oral Pathology. Faculdade Independente do Nordeste. Vitória da Conquista, Bahia, Brasil

[e] Professor, Department of Occlusion, Prosthesis and Dental Material, School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

Corresponding Author:
Dr. Karla Zancopé
Federal University of Uberlândia Department of Oclusion, Prosthesis and Dental Material
Av. Pará, 1720 - Umuarama, Uberlândia, Minas Gerais, Brazil. Zip Code: 38.405-320
Phone number: +55 34 99807-0797 E-mail: karlazancope@gmail.com

ABSTRACT

Mandibular posterior bone atrophy may lead to a series of limitations of treatment options and it is often necessary to initiate with previous reconstructive surgeries. An excellent treatment alternative for atrophic posterior region is the use of short implants (< 7mm long). Transforming a Kennedy Class I patient in a Class III with the use of posterior dental implant it is also an option. The objective of this study is to present a prospective study of 15 consecutive Kennedy Class I patients with atrophic posterior mandible treated with the placement of 1 short implant (WS Neodent®) and a healing screw to support the removable prosthesis, transforming them into Kennedy Class III patients. All patients were evaluated to verify the benefit of this treatment through masticatory performance evaluated with maximum bite force and chewing ability. The OHIP-19 questionnaire was also applied to evaluate changes in oral health-related quality of life. Fifteen patients were followed during research period. Mean patient age was 66.6 years. Results were statistically significant with improvement in masticatory performance for both mixing ability test and maximum bite force evaluation. Also, OHIP-19 improved significatively for parameters concerning physical limitation, pain and discomfort. Implant survival rate in this 3-year follow up was 93.52%, and few complications occurred. The abutment tooth of inferior removable prosthesis also presented good clinical results and improved probing depth of mesial face, bilaterally. Placement of short implants to support RPD in Kennedy Class I mandibular patients transforming into Kennedy Class III patients has advantages such as low cost, residual bone preservation, low morbidity, better masticatory loading distribution, enhanced masticatory function and patient satisfaction. Also, patients may not be able or do not want to perform complex reconstructive surgeries previous to dental implant placement could benefit to this treatment. Additional implants could be placed in the future.

Keywords: Dental implants, masticatory performance, chewing, oral function, mixing ability.

Introduction

The number of patients with partially or multiple edentulism is still increasing.[1] Tooth loss, especially the posterior teeth, may cause a disturbance in the stomatognathic system, affecting sensorial and motor aspects that may interfere with the masticatory process.[2-4] To overcome the absence of the posterior teeth and recompose the aesthetic and masticatory function, a removable partial prosthesis (RPP), fixed partial prosthesis, or implant retained prosthesis are recommended.[2-4]

When the edentulism is posterior and bilateral (Kennedy Class I patient) and a removable dental prosthesis (RPD) treatment is associated some disadvantages.[2-4] Almost 40% of the partially

mandibular edentulous patients are classified as Kennedy Class I and in approximately 60% of these cases patients do not use this prosthesis.[5-7] This treatment is reported to present low retention and stability making chewing difficult and producing pain in the mucosa that is compressed during chewing.[2-6] Increased carious lesions and periodontal disease in the abutment tooth are frequently observed, due to vertical load and presence of clasps.[6-9] During masticatory movements, missadapted prostheses may lead to an excessive load on the residual bone, accelerating its resorption, making the RPD displacement even more evident.[2,10] This can also overload the RPD abutment tooth and lead to periodontal breakdown.[2,10] Aesthetics and inability chew some more consistent food are some of the other complains.[2-6]

Mandibular posterior bone atrophy may lead to a series of limitations of treatment options especially due to anatomical consequences such as low bone quality, often insufficient height and width of residual bone, superficialization of inferior alveolar nerve, and altered or increased occlusal dimension.[2-4,11] For those reasons, when an implant oral rehabilitation is proposed, it is often necessary to initiate with previous reconstructive surgeries. In these cases, some sensitive techniques are subjected to a series of complications.[11] Also, when patients agree to be submitted to complex reconstructive surgeries, they must be aware of the increased cost, treatment time and morbidity. Also, they must be in good systemic conditions. An excellent treatment alternative for atrophic posterior region is the use of short implants.[11,12]

Transforming a Kennedy Class I patient in a Class III with the use of posterior dental implant is described in several studies.[2-10] Since the first systematic review published in 2012, 11 clinical studies were added in the last systematic review published in 2019.[3,4] But there is still a lack of homogeneity between the published studies, in regard to the influence of type and implant position, prosthesis rehabilitation, maxilla or mandible treatment, survival rates, complications, patient evaluation between other topics.[2,5] The consensus in regard of this treatment is that it improves patient overall satisfaction with the RPD, masticatory efficiency, reduces mucosal compression and pain during chewing, protects the RPD abutment tooth and is a low cost and treatment with few complications and reduced time and morbidity associated. Also, torsional and bending forces in the RPD and consequently in the residual bone and the abutment tooth reduces, with positive consequences for both.[2,3,22,28] Few studies have also suggested that an increase in the maximum masticatory force and mandibular motion can be enhanced.[2,3,6,8,16]

Partially edentulous patients may change their nutritive patterns by chewing limitations, which can lead to negative health and nutritional issues, and affect their quality of life.[13-15,29-31] When posterior teeth are lost, it is common for patients to choose softer foods, usually composed of an excess of carbohydrates and lowered in fruits, vegetables, proteins, and nuts, which consequently makes a

less nutritive diet.[13-15,29] Propper masticatory function is so important, that recent studies point to its influence as an activity that protects cognitive function and prevents degenerative diseases of patient's central nervous system.[29-31] Masticatory function may be evaluated through maximum bite force, masticatory performance, or chewing/mixing ability.[33] These methods, which are used to evaluate the masticatory function, have gained great popularity in the latest years, evaluating and comparing treatments and their impact on the quality of life, chewing, and trying to project nutritional aspects for the patients.[2,6-8]

The objective of this study is present a prospective study of 15 consecutive Kennedy Class I patients with atrophic posterior mandible treated with the placement of 1 short implant bilaterally (WS Neodent®) and a healing screw to support the removable prosthesis, transforming them into Kennedy Class III patients. All patients were evaluated to verify the benefit of this treatment through masticatory performance evaluated with maximum bite force and chewing ability. An OHIP-19 questionnaire was also applied to evaluate the oral health-related quality of life. The null hypothesis formulated is that implant placement bilaterally to support patient's inferior RPD would not improve masticatory performance of enhance quality of life.

MATERIALS AND METHODS

Study Design

This was a single-arm clinical trial performed at the school of Dentistry of the Federal University of Uberlandia. This study was approved by the Ethics Committee of this University (CEP/UFU 260/11).

All participants possessed a Kennedy Class I mandibular arch opposing a completely edentulous maxillary arch. Participation was voluntary and involved no patient cost – all participants signed an informed consent explaining the research and treatment plan. All the surgical treatments were performed by a same specialist in oral and maxillofacial surgery (RZA) with 15 years of experience. Variables were accessed between January 2019 and December 2021. Patients were evaluated in regard to masticatory performance through mixing ability test and maximum bite force satisfaction/quality of life through the OHIP-19 questionnaire. Each abutment tooth of the inferior removable partical denture (IRPD) was evaluated through a periapical radiography and periodontal probing. All those mentioned tests and evaluation were previously tested and calibration in a pilot study with 3 consecutive patients.

Patients were evaluated before implant placement (T1) and 1-1,5 year postoperatively (T2). This study was initially planned to be measured in 3 different postoperative moments. The first moments were planned to be 2 to 4 months after implant 2º stage surgery for healing screw placement. Second and third evaluation were planned after 1 and 2 years after initial evaluation. Unfortunately, due to the

COVID-19 pandemics, and the forced closing of the Federal University and public Brazilian services for elective treatments, authors had some setbacks in regard to the initial planning and all the evaluations had to be reduced and accomplished in 1 moment postoperatively. This moment was between 1 and 1 and a Half year after the healing screw was placed over the implant, in the moment of the 2º stage surgery.

Patient Selection

Patients were completely edentulous in the maxillary arch and bilaterally edentulous in the posterior mandible, characterized as Class I Kennedy, with all the anterior remaining teeth. Patients must be wearing adequate total upper complete denture (UCD) and Inferior Removable Partial Denture (IRPD). If necessary, new prostheses were made before surgical treatment. If any other clinical treatment was necessary before surgery, they were also accomplished. Patients must have posterior atrophic mandible, suitable to receive short dental implants, without the need for bone implant reconstruction before implant placement. The bone volume should have between 5 to 8 mm in bone height and 5 to 7mm in bone width. All those measurements were accomplished in a tomographic evaluation. Patients should have good general health without uncontrolled systemic diseases or parafunctional habits that could prevent the proposed surgery or treatment.

The number of patients was based in previous literature reports with sample calculation of a minimum of 9 patients for a study with 80% power and 5% error probability.[15,32] Total number of patients was fixed in 14, due to possible withdraws that might occur during the research. After the initial patient search and selection, the study started with 18 patients. During this 3-year follow-up, 3 withdraws occurred due to different reasons. A total number of 15 patients were enrolled in this study (Table 1).

All implants were Neodent® Titamax WS Medular short implants. These implants have internal prosthetic screwed-in connical connection and triangular cutting threads, indicated for type III and IV bone, characteristic of the posterior mandibular bone. Implants were available in 4- or 5-mm width and 5 or 6mm height. All patients were initially evaluated clinically and with panoramic and periapical radiography (Figure 1). If patients enrolled the inclusion criteria and consent to the proposed treatment, tomographic scanning were accomplished to finalize the evaluation of the inclusion criteria for bone atrophy and to start treatment and surgical planning (Figure 2).

Surgery Protocol

All surgeries underwent the same protocol and were accomplished by the same experienced surgeon and familiarized with Neodent® WS short implant system. Implants were placed at a

maximum of 3 units of teeth after the abutment tooth of the IRPD, in the first or second molar region. In other words, the most distal remaining teeth were incisors or canines (and consequently they were the abutment teeth of the IRPD), the implant would be placed in the 1º molar region. If the last teeth were premolars, the implant would be placed in the 2º molar region. All surgeries were accomplished under local anesthesia in an outpatient manner, with minimal incision and surgical trauma. All implants were placed following the sequence and recommendations of the manufacturer. A surgical guide and a parallelizer guided the proper tridimensional position of the implant. This implant is meant to be placed by the level of the bone crest. Figure 3 illustrate some of these surgical steps.

All treatments followed a 2-time surgical protocol, with reopening of the implant 4 months after implant placement for osseointegration purposes. After this period, implants were exposed and a healing screw were placed (Figure 4). In this moment, if necessary, adjustments were made in the IRPD for proper adaptation of the prosthesis and occlusion of the patient. After 1 to 2 months, if necessary and after soft tissue healing and accommodation, healing screws were replaced so they could be at a maximum of 0.5mm above the soft tissue margin. This was accomplished so the dental implant did not receive overload of excessive lateral forces that could jeopardize the treatment and osseointegration as well as avoid overcontact on the IRPD of the patient (Figure 5).

Masticatory Performance Evaluation

Maximum Bite Force: Patients were evaluated through a bite force transducer (IDDK Kratos, Cotia-SP, Brazil). Patients bit 5 times in the right and 5 times in the left side in the first molar region. Mean value of the sum of the 5 bite measurements were calculated. All those procedures were applied in T1 and T2. Patients were instructed to bite with the maximum force they could all the 5 times tested (Figure 6).

Mixing Ability Test: This evaluation was accomplished with a chewing gum and visual evaluation and classification of the degree of the mixed gum. Current literature supports that for patients with compromise or reduced masticatory function (for instance, edentulous patients with RSP and/or IRPD) this test is more suitable than comminution tests that uses harder test foods such as Optosil/Optocal and sieving methods to evaluate the results. The hardness of this food test materials might influence or prevent a proper masticatory performance of this group of patients.[33-35] The mixing ability test was done with the a two-colored chewing gum (Vivident Fruitswing Karpuz/Asai Üzümü, Perfetti van Melle, Turkey) served as the test food. This chewing gum has 2 distinct colors, purple and green and has already been tested in other studies for similar purposes. The test food was chewed in 5 different masticatory cycles, with, 5, 10, 20, 30 and 40 strokes. After each masticatory cycle, the chewed gum was visually evaluated by 2 independent evaluators e classified in regard to its mixture

level (Figure 7).

Patients were seated comfortably and all tests were performed chewing in the right side of the mouth. Number of masticatory strokes (chewing cycles) was counted always by the same observer. One-minute interval was used between each test to avoid muscle fatigue. All cycles were determined randomly. All chewed gum were evaluated blindly after the patients finished all the 5 masticatory cycles. After that, all the cycles was photographed using the same protocol and saved in a JPEG format. Reference rating scale used to categorize the specimens is already validated in the literature[34,35] to evaluate the level of mixture a 2-color gum for mixing ability test: Score 1 – gum not mixed, cuspid impression or 1-time folded; Score 2 – large parts of the gum not mixed; Score 3 – bolus slightly mixed; Score 4 – bolus well mixed, but color not uniform; and Score 5 – bolus perfectly mixed and color uniform. Those parameters and protocols for evaluation chewing gums for mixing abilities tests has already been verified, tested and validated in the current literature [36-40]

Oral Health Impact Profile (OHIP-19)

OHRQoL evaluation was evaluated through the OHIP-19 questionnaire. This is validated a questionnaire and that has been adapted for use in the Brazilian edentulous population.[41] This questionnaire was applied in T1 and T2 and composed with 19 questions, divided in 7 subgroups or categories which are: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. The complete questionnaire and questions are available in supplementary data (Table 6). Answer options can be never, sometimes or always. For measurement of results, a conversion of the qualitative answers to a quantitative evaluation was accomplished. The researcher that applied the questionnaire was not the surgeon who performed all surgeries, so patients would not feel inhibited in giving the most sincere answer they would like to answer.

Evaluation of the IRPD abutment tooth

The abutment tooth of the IRPD was accomplished throw periodontal probing and periapical radiography. It was hypothesized that with the placement of the healing screw and support of the IRPD over it, transforming in a Kennedy Class I to a Class III mandibular patient, the abutment tooth would suffer from less masticatory load and might present stable or even increase the probing depth evaluation and periapical bone height. Clinical periodontal probing was accomplished in a standard manner, with probing depth of vestibular, mesial, distal and lingual faces of both abutment tooth.

Statistical Analysis

Data were tabulated (Excel for Windows, 365 version) e then exported a statistical package (IBM SPSS Statistics – Version 21.0). Initially the between-examiner agreement test for visual analysis of the chewing gum was verified by the Kappa test. Results pre-operative and post-operative for visual analysis of mixing ability test (visual analysis of the chewing gum), demonstrated a good level of agreement between the observers (pre-Kappa 0,65 and post Kappa 0,72, $p<0,05$). Then, for numeric variables, it was accomplished the normal distribution test of Kolmogorov-Smirnoff.

Chi-square test and the exact Fisher test were also used. Both evaluation from the observers were united, in the pre-operative (T1) and post-operative (T2) periods, therefore having, a total number of 30 "participants". To compare means values of the tests, a paired Student's T tests were used for samples with normal distribution and the Wilcoxon test for samples with non-normal distribution. For the evaluation of the OHIP-19 qualitative questionnaire, scores were given to the answers for means of a quantitative evaluation (1 - never; 2 - sometimes and 3 - always) and then the means of these scores were compared, in a paired manner. The level of significance was set at 5%.

RESULTS

Subjects

Eighteen patients started the study and implants were placed. Three patients dropped out the study during the follow up period; all justified health issues to not attend to appointments due to COVID-19 restrictions.

The age of participats ranged from 55 to 81 years (mean age 66.6 years; 6 male and 9 female). A total of 36 implants were installed. Two implants were lost in a 3-year follow-up, with a cumulative survival rate of 93.5%. Only 30 implants were considered for statistical analysis of masticatory performance, OHIP-19 questionnaire and probing depth. A total of 13 implants were 4 x 5mm and 17 implants were 4 x 6 mm (Neodent WS Implants). All demographic data from 18 patients and complications associated are described in Table 1. All collected data from 15 patients for quantitative and statistical analysis can be found in Table 8 (supplementary data).

Masticatory Performance Evaluation

Maximum bite force increased significantly after the IRPD was supported by implants and healing screw, for both right (p -0009) and left side (p -005), comparing T1 and T2 (Table 2). When both sides were compared between themselves, before or after the implant was placed, there was no significative difference (Table 3).

For the Mixing Ability Test results were statistically significant for 5, 20, 30 and 40 masticatory

cycles between preoperative (T1) and postoperative period (T2). The visual evaluation from both observers (R.Z.A. and R.O.D.), was added to total number of chewed gums in all 5 moments of masticatory cycles, totalizing 30 chewed gums for each of cycles for all patients (Table 4).

The level of agreement between observers for visual analysis was also tested. First, both observers were calibrated in a pilot study. The number of cycles, visual analysis and its 5 different classifications based on the level of the mixed color of the gum, has already been validated in the literature.[33,34] The results of the level of agreement between the observers was substantial, giving a good weight to visual evaluation for mixing ability test for masticatory performance purpose (Table 5). Results for 10, 20, 30 cycles were substantial and the postoperative cycle of 5 strokes and 40 strokes were perfect. It is a sensitive test and just a few numbers of disagreement between the observers can lead to poor results. Both pre- and post-operatively were substantial (Table 5).

Oral Health Impact Profile (OHIP-19): results where statically significant for all 3 questions on functional limitation (questions number 1, 2 and 3), and for physical limitation (questions number 10, 11, 12). Also, they improved in 2 of 4 for physical pain (questions number 5 and 7), and for 1 of 2 for psychological limitation (question number 14) (Table 6). For the other qualitative group of questions which were, physical psychological discomfort (questions number 9 and 10); social limitation (questions number 15, 16 and 17) and handicap/incapacity (questions number 18 and 19), there was no significative changes or improvement (Table 6).

IRPD clinical Probing Depth: Clinical probing depth was significative improved in both mesial faces of the IRPD abutment teeth (Table 7). In the left side, the lingual side also showed significative improvement. Vestibular and distal sides did not show improvement from the baseline clinical probing depth.

DISCUSSION

In this study, the null hypothesis was rejected, meaning that implant placement led to significantly better masticatory performance and OHRQoL. Also, the IRPD abutment teeth showed good clinical results in the postoperative evaluation.

In the past years, studies that focus on the relationship between masticatory function, its systemic benefits, nutritional status and quality of life has been deeply studied and discussed.[42-44] Recent studies have related a proper masticatory function and its influence as an activity that protects cognitive function and prevents central nervous system degenerative diseases.[45-48] The RPD for Kennedy Class I patients may lead to poor retention, stability, and due to the absence of support in the posterior teeth, the mucosa is compressed when chewing is taking place, producing pain and discomfort.[42,49] This

treatment is associated with overall dissatisfaction and, in approximately 60% of the cases, patient abandon the use of this prosthesis.[2,13,21] When Kennedy Class I patients seek for other treatment options, it is quite common to present with mandibular posterior bone atrophy. In these cases, it is often necessary to initiate with previous reconstructive surgery, which are often sensitive techniques with potential to increase treatment costs, time and morbidity considerably.[12-14] An excellent treatment alternative for the atrophic posterior region avoiding several of this issue is the use of short implants.[7,51]

It is important to mention the overall survival rate of 93.5% for short implants (Neodent WS) in the 3-year follow up in our study. Both losses happened before the loading of the healing screw, in the moment of the 2º-stage surgery, due to lack of osseointegration. Some aspects may affect the osseointegration of short implants in cases of atrophic posterior mandible. One of them is the presence of dense cortical walls (vestibular, lingual and crestal) in an atrophic bone. In some cases, is the "only available bone" to place the dental implant and this is not the "ideal" bone since it can has less blood supply vascularity and available bone cells to interact biologically to the titanium implant over time. It is worth remembering and mentioning that all these cases were cases of atrophic mandible, and in some of them, the available alveolar bone was the limit between bone availability and implant size. Approximately 5-6mm in alveolar bone height and 5mm in alveolar bone thickness for a 4x5mm thick implant and bone height. This may lead to a lack of adequate blood supply to promote bone repair, which can be intensified when implants are installed with high torques.[51-53] Also, this is an implant indicated by the manufacturer (Neodent®) to be placed at the crestal level, and it is expected that some degree of bone resorption due to the surgical trauma and the years to come will take place.[51-54] For a short implant, this "natural" peri-implant bone loss can be proportionally significative.[52-54] Due to anatomic characteristics, some of the cases were placed in an intra-osseous manner, an showed good clinical results.[52,55] This is an issue to be further investigated, if the placement of short implants one or 2mm intra-osseous can lead to better clinical and radiological results, with better survival rates. The surgeon experience and especially the Morse taper connection played an important role in the stability of the healing screw and the low incidence of complications of the treatment.[52,56-58]

Placement of short implants to support bilateral free end mandibular prosthesis is being published in the literature.[2-9, 13-16,18-28] This treatment has some advantages for the patient such as low treatment cost, preservation of the residual bone, reduced morbidity treatment option, better loading distribution in the pillar removable prosthesis teeth (and increased tooth survival), increased speech ability and masticatory function, better prosthesis stability and comfort during chewing, and ultimately, enhanced satisfaction and patient quality of life.[2-9] It has already been suggested that 3 masticatory units are sufficient to create a significative positive outcome in the masticatory performance of patients (short dental arch).[2] In our study, placement of the implant, if in the 1º or 2º molar region, would depend on

the remaining abutment teeth.[3] The position of the short implant must be carefully planned to aim the support the RPD and even make it possible (if so desired), to the placement of additional implants for a fixed partial prosthesis. Systematic reviews demonstrated good survival rates for this type of treatment, varying between 91.7 - 100%, similar to other mandibular regions used exclusively to support implant fixed prosthesis, which are in agreement this study.[3,5] Only 1 study used short implant (4mm implants) in the mandible and a locator attachment for Kennedy class I and II patients to support an IRPD.[17] They had 2 losses, with survival rates within a 4-year follow-up of 94.3%, similar to these results.[17]

These results demonstrated the improvement of masticatory performance, when evaluating the parameters of mixing ability and maximum bite force. It may be considered that the visual assessment and classification for the mixing ability test, despite following a measurement that is standardized and validated in the literature, may have some subjectivity. To increase the reliability of results and assessment, both evaluators were calibrated in a pilot study and the results of their evaluations in these studies were tested with good level of agreement. An interesting result observed in regard to the mixing ability test was the significant difference in a few chewing cycles, in this case, with only 5 masticatory cycles. This result was not initially expected, since a small number of masticatory cycles, in general, for a treatment that does not present a very significant change in the patient's oral dental rehabilitation, is not expected to present such a large change in the masticatory performance in few chewing cycles.[34,37,39] However, because there is an increase of comfort, adaptation and confidence of patients in chewing and with an increased bite force, these results have been positive. From 20 chewing cycles, these results were already expected to be found significant, as they were for 30 and 40 cycles. The expressive results regarding significant improvement in maximum bite force of patients in postoperative period, proves the effectiveness of the treatment in dividing the masticatory loads and sparing the soft tissues and alveolar bone of the patient. This simple support of a healing screw over an implant transforming a Kennedy Class I patient in a Kennedy class III patient, almost increased in 2 times the maximum bite force of the overall group of patients. It is important to emphasize that although there are several methods and test foods to evaluate the masticatory performance, several studies have already compared, validated and studied the chewing gum for these purposes.[33-37] In general, the use of chewing gums to evaluate mixing ability is justified to have some advantages as a test food, i.e., simplicity of application, texture and flavor pleasant to the patient, non-adherence to prostheses and quick and simple to be performed. Also, the evaluation method employed to obtain the results is considered simple, reliable and with low cost.[33-36] Literature suggest that 20 masticatory cycles already has the potential to discriminate and compare patients and treatments.[33,34]

OHIP-19 questionnaire is developed from the OHIP-49 questionnaire. This is a validated and

translated questionnaire adapted and its reliability and reproducibility tested and validated for a Brazilian edentulous population.[59,60] The OHIP questionnaire determines the impact oral conditions on aspects of function, daily living, and social interactions in seven domains.[60] These results clearly show us that the improvement of these patients is Physical and Functional. There is a direct improvement in the matter of having a better distribution of masticatory loads without overloading the mucosa and alveolar bone, allowing the patient to have a proper masticatory function and to chew harder foods, without generating pain in the edentulous region and produce functional limitation. We might extrapolate in a qualitative point of view, that the patients' nutritional pattern is expected to improve, as with a better masticatory performance, it allows the possibility to enhance the diet profile, including harder and more consistent foods, such as almonds, fruits, vegetables, protein and more fibrous food. Studies have already mentioned the improvement and change in nutritional pattern with the increase in masticatory performance diverse oral treatment.[13,61-63]

The clinical follow-up was positive regarding the RPD abutment tooth. Radiographically, changes at the level of the alveolar bone were not observed. The results showed an improvement, with a decrease in probing depth especially on the mesial faces in both abutment teeth bilaterally. This is an interesting result, because due to the support of the niche and the RPD clasp resting on the distal face of the abutment tooth, it was expected to be on the distal face of the abutment teeth. The improvement, however, was on the mesial face, which shows that this face also suffers from occlusal overload, and is also benefited from the better distribution of occlusal loads. In regard to have good clinical results and stable periodontal status, our results are similar to some clinical trials reported in the literature.[24, 64-66]

Placement of short implants to support RPD in Kennedy Class I mandibular patients transforming in Kennedy Class III patients has advantages such as low cost, residual bone preservation, low morbidity, better masticatory loading distribution, and enhanced masticatory function and patient satisfaction. This treatment was associated with very few complications and they were easy to solve (i.e. healing screw changes that can be loosen, although this was not common). Especially in countries with many patients with missing teeth and socio-economic difficulties to be fully rehabilitated with dental implants and fixed prosthesis treatment options with reduced costs are important to be in armamentarium of possibilities. Also, patients may not be able or do not want to perform complex reconstructive surgeries previous to dental implant placement, and if necessary or if they want, they can evolve to the insertion of a full crown and additional implants in the future. This are preliminary results and further follow-up up to 5 and 10 years are planned, including periapical radiographic measurement of bone loss around the implant as an added parameter to be evaluated.

References

1. Cardoso M, Balducci I, Telles D de M, Lourenço EJV, Nogueira Júnior L. Edentulism in Brazil: trends, projections and expectations until 2040. Cien Saude Colet. 2016; 21(4): 1239-46.
2. Zancopé K, Abrão GM, Karam FK, Neves FD. Placement of a distal implant to convert a mandibular removable Kennedy class I to an implant-supported partial removable Class III dental prosthesis: A systematic review. J Prosthet Dent 2015; 113:528-533.
3. Park JH, Lee J-Y, Shin S-W, Kim S-J. Effect of conversion to implant-assisted removable partial denture in patients with mandibular Kennedy classification: A systematic review and meta-analysis. Clin Oral Impl Res. 2020; 31:360–373.
4. de Freitas RFCP, Dias Carvalho K, Carreiro AFP, Barbosa GAS, Ferreira MAF.Mandibular implant-supported removable partial denture with distal extension: a systematic review. J Oral Rehabil 2012;39:791-8.
5. Bassetti, R. G., Bassetti, M. A., & Kuttenberger, J. (2018). Implant-assisted removable partial denture prostheses: A critical review of selected literature. The International Journal of Prosthodontics, 31(3), 287–302. https://doi.org/10.11607/ijp.5227
6. Gonçalves TMSV, Campos CH, Gonçalves GM, de Moraes M, Rodrigues Garcia RCM. Mastication improvement after partial implant-supported prosthesis use. J Dent Res. 2013; 92(12).
7. Wismeijer D, Tawse-Smith A, Payne AGT. Multicentre prospective evaluation of implant-assisted mandibular bilateral distal extension removable partial dentures: Patient satisfaction. Clin Oral Implants Res. 2013; 24(1):20–7.
8. Gonçalves TMSV, Campos CH, Gonçalves GM, de Moraes M, Rodrigues Garcia RCM. Mastication improvement after partial implant-supported prosthesis use. J Dent Res. 2013; 92(12).
9. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Mastication and jaw motion of partially edentulous patients are affected by different implant-based prostheses. J Oral Rehabil. 2014;41(7):507–14.
10. Kern M, Wagner B. Periodontal findings in patients 10 years after insertion of removable partial dentures. J Oral Rehabil 2001;28:991-7
11. Blackburn TK, Cawood JI, Stoelinga PJW, Lowe D. What is the quality of the evidence base for pre-implant surgery of the atrophic jaw? Int J Oral Maxillofac Surg 2008;37(12):1073–1079
12. Pistilli R., Felice P., Cannizzaro G., Piatelli M., Corvino V., Barausse C., Buti J., Soardi E., Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long 4 mm wide implants or by longer implants in augmented bone. One-year post-loading results from a pilot randomised controlled trial. Eur. J. Oral Implant. 2013;6:359–372.
13. Goncalves TMSV, Campos CH, Garcia RCMR. Effects of Implant-Based Prostheses on Mastication, Nutritional Intake, and Oral Health–Related Quality of Life in Partially Edentulous Patients: A Paired Clinical Trial. Int J Oral Maxillofac Implants. 2015; 30(2): 391-6.

14. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Implant retention and support for distal extension partial removable dental prostheses: Satisfaction outcomes. J Prosthet Dent. 2014; 112(2):334–9.
15. Campos CH, Gonçalves TMSV, Rodrigues Garcia RCM. Implant retainers for free-end removable partial dentures affect mastication and nutrient intake. Clin Oral Implants Res. 2014; 25(8):957–61.
16. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Mastication and jaw motion of partially edentulous patients are affected by different implant-based prostheses. J Oral Rehabil. 2014;41(7):507–14.
17. Bella E, Audenino G, Ceruti P, Bassi F. Clinical assessment of short implants renatining removalbe partial dentures: 4-year Follow-up. Int J Oral Maxillofac Implants 2020:35;207-213.
18. El Mekawy NH, El-Negoly SA, Grawish Mel-A, El-Hawary YM. Intracoronal mandibular Kennedy Class I implant-tooth supported removable partial overdenture: a 2-year multicenter prospective study. Int J Oral Maxillofac Implants 2012;27:677-83.
19. Praveen M, Chandra Sekar A, Saxena A, Gautam Kumar A. A new approach for management of Kennedy's class I condition using dental implants: a case report. J Indian Prosthodont Soc 2012;12:256-9.
20. Elsyad, M. A., & Habib, A. A. (2011). Implant-supported versus implant- retained distal extension mandibular partial overdentures and residual ridge resorption: A 5-year retrospective radiographic study in men. The International Journal of Prosthodontics, 24(4), 306–313.
21. Shahmiri RA, Atieh MA. Mandibular Kennedy Class I implant-tooth-borne removable partial denture: A systematic review. J Oral Rehabil. 2010; 37(3):225-34.
22. Oh, W. S., Oh, T. J., & Park, J. M. (2016). Impact of implant support on mandibular free-end base removable partial denture: Theoretical study. Clinical Oral Implants Research, 27(2), e87–e90. https://doi. org/10.1111/clr.12534
23. Keltjens HM, Kayser AF, Hertel R, Battistuzzi PG. Distal extension removable partial dentures supported by implants and residual teeth: considerations and case reports. Int J Oral Maxillofac Implants 1993;8:208-13.
24. Ohkubo, C., Kobayashi, M., Suzuki, Y., & Hosoi, T. (2008). Effect of implant support on distal-extension removable partial dentures: In vivo assessment. International Journal of Oral and Maxillofacial Implants, 23(6), 1095–1101.
25. Jensen, C., Meijer, H. J. A., Raghoebar, G. M., Kerdijk, W., & Cune, M. S. (2017). Implant-supported removable partial dentures in the mandible: A 3–16 year retrospective study. Journal of Prosthodontic Research, 61(2), 98–105. https://doi.org/10.1016/j.jpor.2016.07.002
26. Jensen, C., Speksnijder, C. M., Raghoebar, G. M., Kerdijk, W., Meijer, H. J. A., & Cune, M. S. (2017). Implant-supported mandibular removable partial dentures: Functional, clinical and radiographical parameters in relation to implant position. Clinical Implant Dentistry and Related Research, 19(3), 432–439. https://doi.org/10.1111/cid.12484

27. Suzuki, Y., Kono, K., Shimpo, H., Sato, Y., & Ohkubo, C. (2017). Clinical evaluation of implant-supported removable partial dentures with a stress-breaking attachment. Implant Dent, 26(4), 516–523. https:// doi.org/10.1097/ID.00000 00000 000592
28. Matsudate, Y., Yoda, N., Nanba, M., Ogawa, T., & Sasaki, K. (2016). Load distribution on abutment tooth, implant and residual ridge with distal-extension implant-supported removable partial denture. J Prosthodont Res, 60(4), 282–288. https://doi.org/10.1016/j. jpor.2016.01.008
29. Elsig F, Schimmel M, Duvernay E, Giannelli SV, Graf CE, Carlier S, et al. Tooth loss, chewing efficiency and cognitive impairment in geriatric patients. Gerodontology. 2015;32(2):149-56.
30. Onozuka M, Fujita M, Watanabe K, Hirano Y, Niwa M, Nishiyama K, et al. Age-related changes in brain regional activity during chewing: a functional magnetic resonance imaging study. Journal of Dental Research. 2003;82(8):657-60.
31. Tada A, Miura H. Association between mastication and cognitive status: A systematic review. Arch Gerontol Geriatr. 2017; 70:44-53.
32. van der Bilt A, Olthoff LW, Bosman F, Oosterhaven SP. Chewing performance before and after rehabilitation of post-canine teeth in man. J Dent Res. 1994;73:1677–1683.
33. Vega TMS, Schimmel M, Van der Bilt A, Chen J, Van der Glas HW, Kohyama H, Hennequin M, Peyron MA, Woda A, Leles CR, Pereira LJ. Consensus on the terminologies and methodologies for masticatory assessment. J Oral Rehabil. 2021; 48(6):745-61.
34. Silva L, Nogueira T, Rios L, Schimmel M, Leles C. Reliability of a two-colour chewing gum test to assess masticatory performance in complete denture wearers. J Oral Rehabil. 2018;45(4):301-307.
35. Schimmel M, Christou P, Herrmann F, Muller F. A two-colour chewing gum test for masticatory efficiency: development of different assessment methods. J Oral Rehabil 2007; 34:671–8.
36. Halazonetis DJ, Schimmel M, Antonarakis GS, Christou P. Novel software for quantitative evaluation and graphical representation of masticatory efficieny. J Oral Rehabil 2013; 40:329-35.
37. Speksnijder CM, Abbink JH, van der Glas HW, Janssen NG, van der Bilt A. Mixing ability test compared with a comminution test in persons with normal and compromised masticatory performance. Eur J Oral Sci 2009; 117:580-6.
38. Schimmel M, Christou P, Miyazaki H, Halazonetis D, Herrmann FR, Muller F. A novel colourimetric technique to assess chewing function using two-coloured specimens: Validation and application. J Dent 2015; 43:955-64.
39. Tarkowska A, Katzer L, Ahlers MO. Assessment of masticatory performance by means of a color-changeable chewing gum. J Prosthodont Res. 2017;61(1):9-19
40. Weijenberg RA, Scherder EJ, Visscher CM, Gorissen T, Yoshida E, Lobbezoo F.Twocolour chewing gum mixing ability: digitalisation and spatial heterogeneity analysis. J Oral Rehabil 2013; 40:737-43.
41. Souza RF, Patrocinio L, Pero AC, Marra J, Compagnon MA. Reliability and validation of a Brazilian version of the Oral Health Impact Profile for assessing edentulous subjects. J Oral Rehabil. 2007:34;821–826.

42. Lee, I. C.; Yang, Y. H. & Ho, P. S. (2014). Chewing ability, nutritional status and quality of life. Journal of Oral Rehabilitation, 41(2), 79-86.
43. Locker, D. & Grushka, M. (1987). Prevalence of oral and facial pain and discomfort: preliminary results of a mail survey. Community Dentistry and Oral Epidemiology, 15(3), 169-172
44. Sheiham A, Steele JG, Marcenes W, Lowe C, Finch S, Bates CJ, et al. The relationship among dental status, nutrient intake, and nutritional status in older people. Journal of Dental Research. 2001;80(2):408-13.
45. Elsig F, Schimmel M, Duvernay E, Giannelli SV, Graf CE, Carlier S, et al. Tooth loss, chewing efficiency and cognitive impairment in geriatric patients. Gerodontology. 2015;32(2):149-56.
46. Onozuka M, Fujita M, Watanabe K, Hirano Y, Niwa M, Nishiyama K, et al. Age-related changes in brain regional activity during chewing: a functional magnetic resonance imaging study. Journal of Dental Research. 2003;82(8):657-60
47. Okamoto N, Morikawa M, Okamoto K, Habu N, Hazaki K, Harano A, et al. Tooth loss is associated with mild memory impairment in the elderly: the Fujiwara-kyo study. Brain Research. 2010;1349:68-75.
48. Momose T, Nishikawa J, Watanabe T, Sasaki Y, Senda M, Kubota K, et al. Effect of mastication on regional cerebral blood flow in humans examined by positron-emission tomography with 15O-labelled water and magnetic resonance imaging. Archives of Oral Biology. 1997;42(1):57–61.
49. Oliveira NM, Shaddox LM, Toda C, Paleari AG, Pero AC, Compagnoni MA. Methods for evaluation of masticatory efficiency in conventional complete denture wearers: a systematized review. Oral Health Dent Manag 2014;13:757-62.
50. Curtis DA, Curtis TA, Wagnild GW, Finzen FC. Incidence of various classes of removable partial dentures. J Prosthet Dent 1992;67:664-7.
51. Neves FD, Fones D, Bernardes SR, do Prado CJ, Neto AJ. Short implants--an analysis of longitudinal studies. Int J Oral Maxillofac Implants. 2006;21:86-93.
52. Fernandes GVO, Costa BMGN, Trindade HF, Castilho RM, Fernandes JCH. Comparative analysis between extra-short implants (≤6 mm) and 6 mm-longer implants: a meta-analysis of randomized controlled trial. Aust Dent J. 2022 doi: 10.1111/adj.12900. Article In Press
53. Stellingsma C, Vissink A, Meijer HJ, Kuiper C, Raghoebar GM. Implantology and the severely resorbed edentulous mandible. Crit Rev Oral Biol Med. 2004;15:240-248.
54. Felice P, Soardi E, Pellegrino G, Pistilli R, Marchetti C, Gessaroli M, Esposito M. Treatment of the atrophic edentulous maxilla: short implants versus bone augmentation for placing longer implants. Five-month post-loading results of a pilot randomised controlled trial. Eur J Oral Implantol. 2011;4:191–202
55. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. Int J Oral Maxillofac Implants. 2006;21:275-282.

56. Mangano C, Mangano F, Piattelli A, Iezzi G, Mangano A, La Colla L. Prospective clinical evaluation of 1920 Morse taper connection implants: results after 4 years of functional loading. Clin Oral Implants Res. 2009;20:254-261.
57. Atieh MA, Zadeh H, Stanford CM, Cooper LF. Survival of Short Dental Implants for Treatment of Posterior Partial Edentulism: A Systematic Review. Int J Oral Maxillofac Implants. 2012;27:1323–1331.
58. Vetromilla BM, Mazzetti T, Pereira-Cenci T. Short versus standard implants associated with sinus floor elevation: An umbrella review of meta-analyses of multiple outcomes. J Prosthet Dent. 2021;126:503-511.
59. Pires CPAB, Ferraz MB, de Abreu MHNG. Translation into Brazilian portuguese, cultural adaptation and validation of the oral health impact profile (ohip-49). Braz Oral Res 2006;20(3):263-8
60. Oliveira BH, Nadanovsky P. Psychometric properties of the Brazilian version of the Oral Health Impact Profile–short form. Community Dent Oral Epidemiol 2005; 33: 307–14.
61. Liedberg B, Norlen P, Owall B, Stoltze K. Masticatory and nutritional aspects on fixed and removable partial dentures. Clin Oral Investig 2004;8:11–1713
62. Kagawa R, Ikebe K, Inomata C, et al. Effect of dental status and masticatory ability on decreased frequency of fruit and vegetable intake in elderly Japanese subjects. Int J Prosthodont 2012;25:368–375.
63. Awad MA, Morais JA, Wollin S, Khalil A, Gray-Donald K, Feine JS. Implant overdentures and nutrition: A randomized controlled trial. J Dent Res 2012;91:39–46.
64. Bortolini S, Natali A, Franchi M, Coggiola A, Consolo U. Implant-retained removable partial dentures: an 8-year retrospective study. J Prosthodont 2011;20:168-72
65. Mitrani R, Brudvik JS, Phillips KM. Posterior implants for distal extension removable prostheses: a retrospective study. Int J Periodontics Restorative Dent 2003;23:353-9.
66. Mijiritsky E, Ormianer Z, Klinger A, Mardinger O. Use of dental implants to improve unfavorable removable partial denture design. Compend Contin Educ Dent 2005;26:744-6, 748, 750 passim.

FIGURES

Figure 1 – Preoperative intraoral photographs. A, B, C. Preoperative intraoral photographs using upper complete denture and lower partial denture. D, E, F. Frontal and lateral intraoral photograph without the removable dentures showing residual ridge depth and bone atrophy. G, H, I. Photographs of the upper complete denture and lower partial denture used by the patient before implant placement

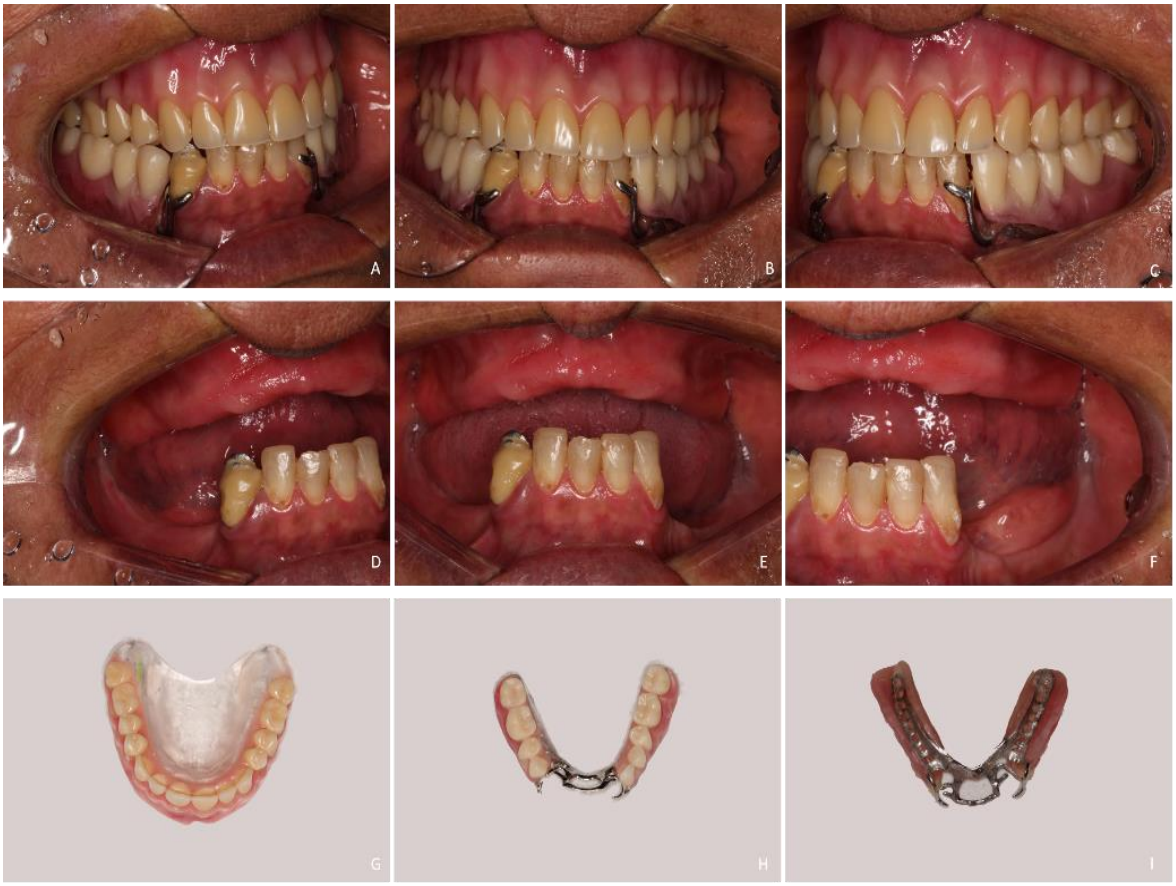


Figure 2 – Preoperative radiographic and tomographic images. A. Preoperative panoramic radiography. B and C, Periapical radiographs of the pillar teeth for the removable prosthesis, the right canine, and left lateral incisor. D, E. Computed tomography of the regions planned for implant placement. It is possible to see the bone atrophy on the mandibular posterior region on both sides.

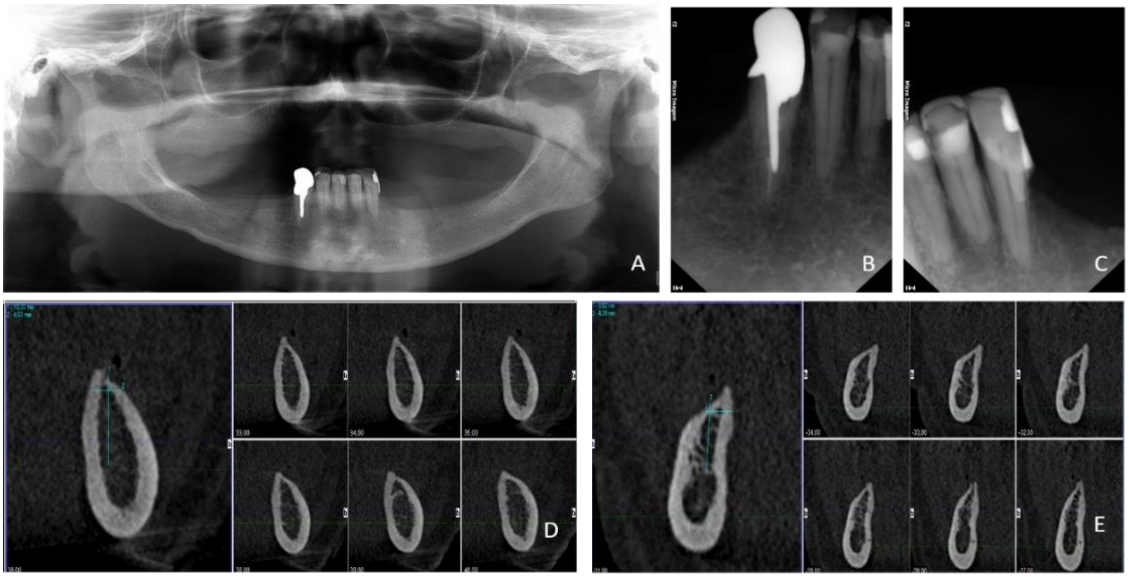


Figure 3 – Implant surgery placement. All surgeries followed the same protocol. A. Alveolar ridge incision and periosteal tissue detachment. B. After the 2.0 drilling, a parallelizer was placed to check the correct

tridimensional position of the implant to be inserted. C. Implant engaged and torque measuring. D. Implant installed with a cover screw in a bone level manner.

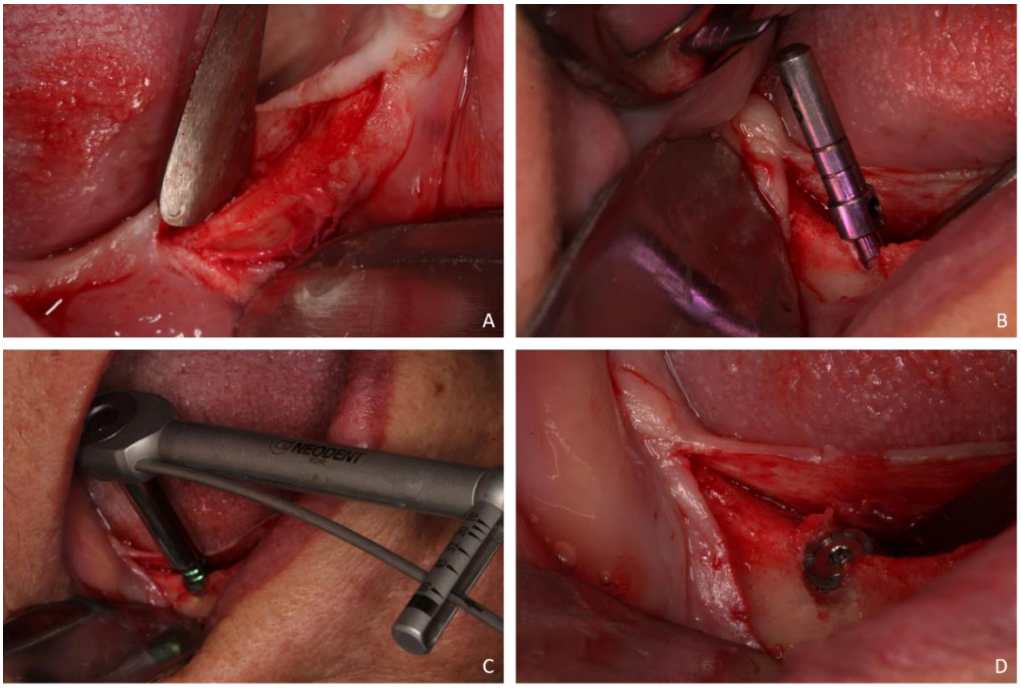


Figure 4 – Reopening surgery after 4 months of osseointegration period. A,C. A small incision is accomplished to expose the implant. B, D. Silk suture was placed on both sides after the cover screw was properly selected and torqued.

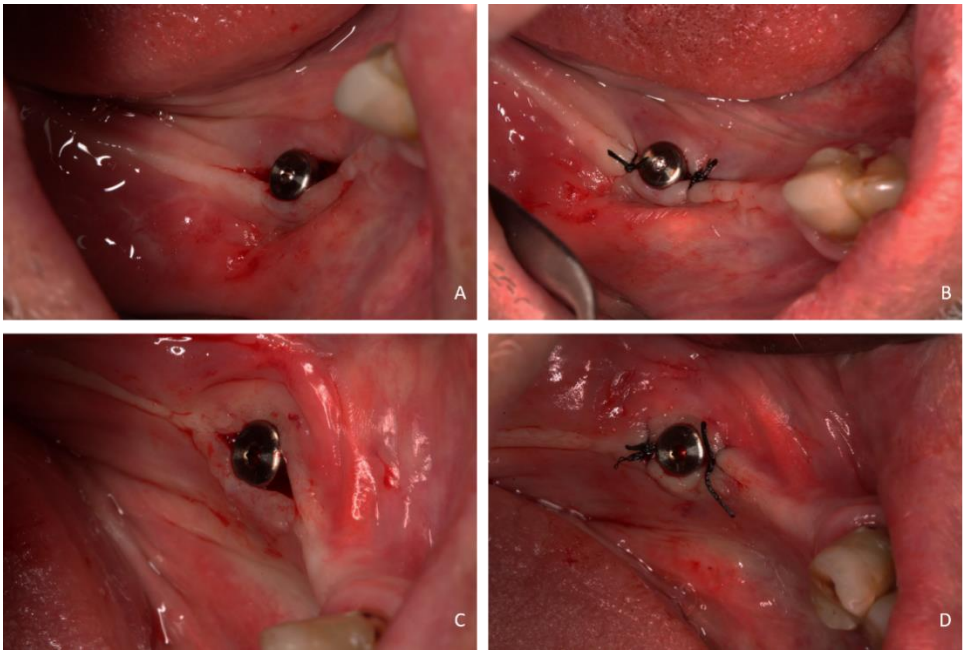


Figure 5 – In the follow-up periods, if the healing screw were more than 1mm above the soft tissues, they were changed to a smaller one. A, C. Soft tissue aspect without the healer bilaterally. B, D. Replacement of the healer

on the right side and left side respectively.

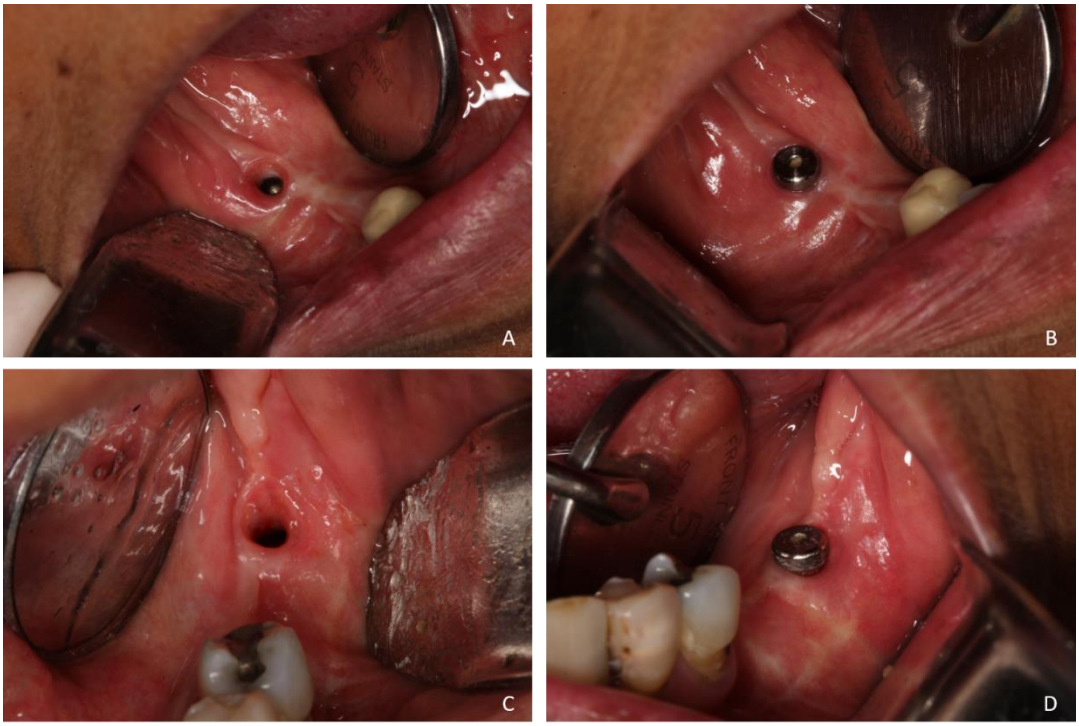


Figure 6 – Measurement of the maximum bite force with the Bite Force Transducer (Gnatodynamometer).

Figure 7 – Photographic image of the chewed gum for visual assessment for the mixing ability test evaluation. A, Chewed gum after 5 chewing cycles. B, Chewed gum after 10 chewing cycles. C, Chewed gum after 20 chewing cycles. D, Chewed gum after 30 chewing cycles. E, Chewed gum after 40 chewing cycles.

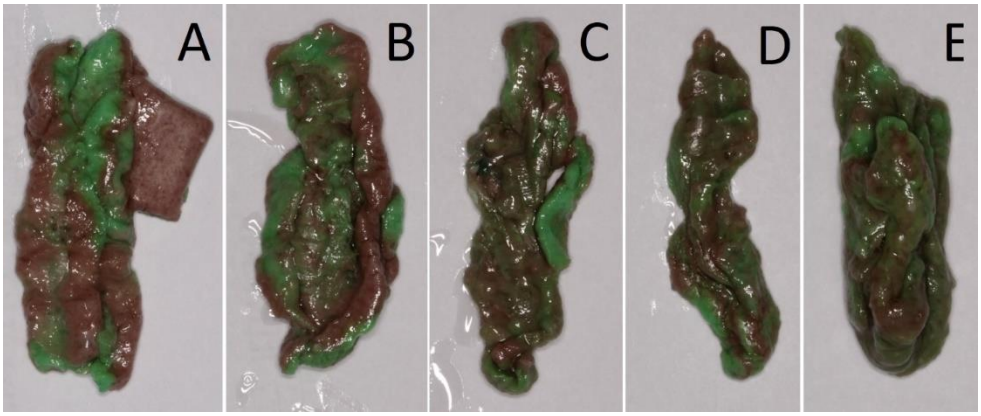
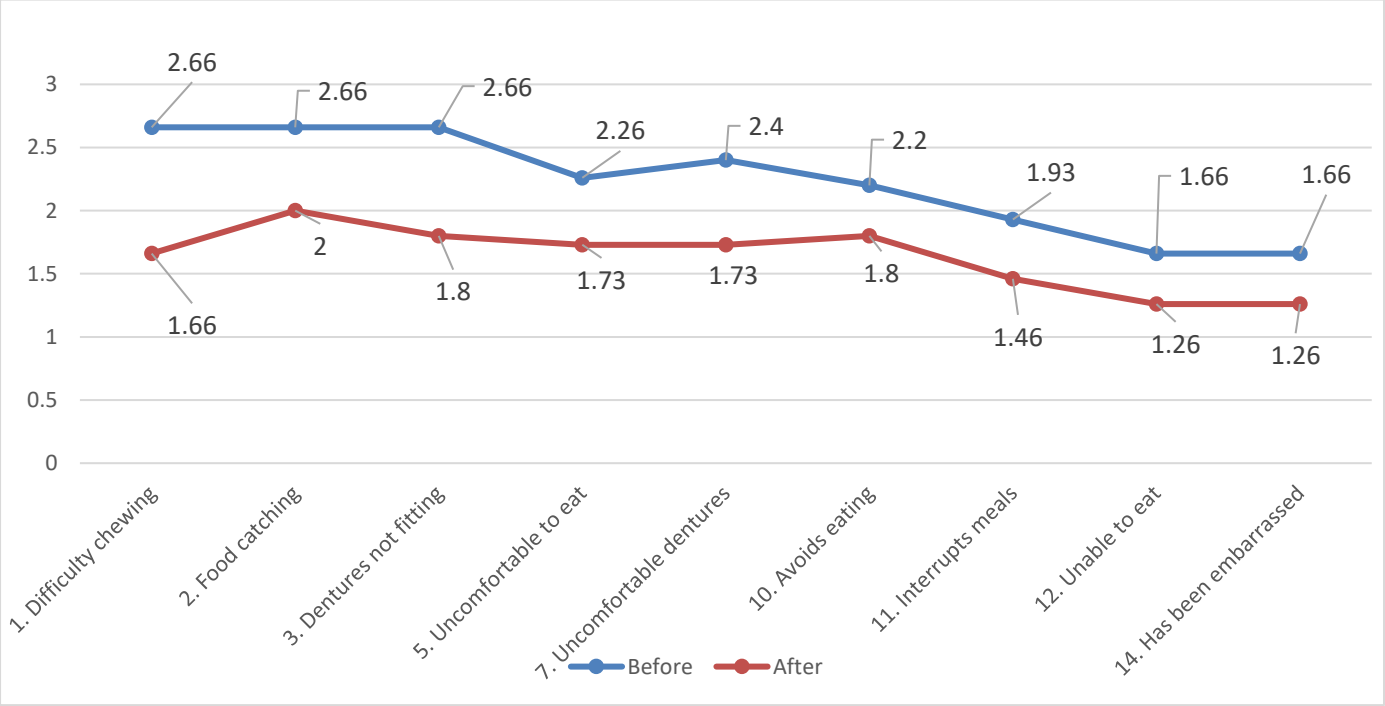


Figure 8. OHIP-19 scale results. The questions are related to the group of qualitative domains: 1,2,3 Functional limitation; 4, 5, 6,7 Physical Pain; 8 , 9 Psychological discomfort; 10, 11, 12 Physical limitation; 15, 16, 17 Social limitation; 18, 19 – Incapacity/Handicap.



TABLES

Table 1. Demographic data from the 18 consecutive patients. 03 patient's dropout the during the follow-up period. 15 patients were included for statistical analysis. 02 implants were lost before healing screw were placed and new implants were installed surgically

Patient	Age	Gender	Systemic Condition	Implant Size	Healing Screw	Complication
1	70	Male	Hypertension Heart Surgery	4x6 4x6	1,5mm LS (was 3.5) 2,5mm RS (was 3.5)	

2	67	Female	Diabetes Hypertension	4x6 4x5	0,8mm LS (was 3.5) 2,5mm RS (was 3.5)	
3	62	Female	Hypertension Diabetes Hypothyroidism	4x6 4x6	2,5mm LS (was 3.5) 0,8mm RS	Pain
4	59	Male	-	4x5 4x5	1,5mm LS 3,5mm* RS (was 2.5)	
5	58	Female	Diabetes	4x5 4x5	0,8mm LS (was 1.5) 0,8mm RS (was 2.5)	
6	75	Male	Hypertension Artrosis	4x5 4x6	2,5mm LS (was 3.5) 1,5mm RS (was 2.5)	
7	78	Male	Cerebrovascular accident	4x6 4,6	1,5mm RS (was 2.5) 1,5mm LS (was 2.5)	
8	81	Male	Hypertension Hipercolesterolemia	4x6 4x6	1,5mm LS 0,8mm RS	
9	62	Female	-	4x5 4x5	1,5mm LS (was 2.5) 3,5mm* RS (was 2.5)	Pain
10	78	Female	Diabetes Hypertension Heart Surgery	4x5 4x5	3,5mm LS 3,5mm RS	01 implant loss
11	67	Female	-	4x6 4x6	1,5mm LS 2,5mm RS	-
12	66	Male	Hepatitis C	4x5 4x6	2,5mm RS 1,5mm LS	01 implant loss
13	60	Female	-	4x6 4x6	3,5mm LS 2,5mm RS	-
14	64	Female	Diabetes Hypertension	4x5 4x5	1,5mm LS 0,8mm RS	-
15	55	Female	Hypertension Arthritis Uterus Surgery	4x6 4x6	1,5mm LS 0,8mm RS	
16 Dropout		*Female*	*Hypertenstion* *Diabetes*	*4x5* *4x6*	*?*	-
17 Dropout		*Female*	-	*4x6* *4x6*	*3,5mm LS* *O,8mm RS*	-
-18 Dropout		*Female*	-	*4x5* *4x5*	*?*	-

Table 2. Maximum bite force (MBF). The mean values are measured in Kg/F. They were evaluated in the right and in the left side in the First Molar Region. Results were significant in the pre-operative (T1) and post-operative evaluation (T2).

Maximum Bite Force (MBF)

		Mean	N	Deviation error	p
Right side	T1 MBF	6,5264	15	4,66744	**0,009***
	T2 MBF	10,8987	15	8,68034	
Left side	T1 MBF	7,0101	15	3,55712	**0,005***
	T2 MBF	11,4813	15	7,41363	

Table 3. Comparative Maximum bite force between right and left side in T1 and in T2. There was no significative difference between MBF comparing patient sides.

Mean Maximum Bite Force Right side X Left side

		Mean	N	Deviation error	P
Right side	T1 Right Side	6,7220	15	4,56099	0,690
	T1 Left Side	7,0101	15	3,55712	
Left side	T2 Right Side	10,8987	15	8,68034	0,318
	T2 Left Side	11,6736	15	7,65459	

Table 4. Mixing Ability Test. There are 5 visual scales 1. Gum not mixed, cuspid impression or 1 time folded; 2. Large parts of the gum not mixed; 3. Bolus slightly mixed; 4. Bolus well mixed but color not uniform; 5. Bolus perfectly mixed and color uniform. For statistical mean purposes, it was added the visual evaluation from both observers, RZA and ROD, totalizing a n of 30 chewed gums.

Masticatory cycle	**T1 – Chewed gum description**	**n**	**%**	**T2 – Chewed gum description**	**n**	**%**	**p**
05 cycles							
	1. Gum not mixed, cuspid impression or 1 time folded	21	70,0%	1. Gum not mixed, cuspid impression or 1 time folded	5	16,7%	**0,013***
	2. Large parts of the gum not mixed	9	30,0%	2. Large parts of the gum not mixed	22	73,3%	
	3. Bolus slightly mixed	0	0%	3. Bolus slightly mixed	3	10,0%	
10 cycles							
	1. Gum not mixed, cuspid impression or 1 time folded	8	26,7%	1. Gum not mixed, cuspid impression or 1 time folded	0	0%	0,52
	2. Large parts of the gum not mixed	19	63,3%	2. Large parts of the gum not mixed	15	50,0%	
	3. Bolus slightly mixed	3	10,0%	3. Bolus slightly mixed	14	46,7%	
	4. Bolus well mixed but color not uniform	1	3,3%	4. Bolus well mixed but color not uniform	1	3,3%	
20 cycles							
	1. Gum not mixed, cuspid impression or 1 time folded	6	20,0%	1. Gum not mixed, cuspid impression or 1 time folded	0	0%	**0,000***
	2. Large parts of the gum not mixed	11	36,7%	2. Large parts of the gum not mixed	5	16,7%	
	3. Bolus slightly mixed	13	43,3%	3. Bolus slightly mixed	18	60,0%	
	4. Bolus well mixed but color not uniform	0	0%	4. Bolus well mixed but color not uniform	7	23,3%	
30 cycles							

	1. Gum not mixed, cuspid impression or 1 time folded	2	6,7%	1. Gum not mixed, cuspid impression or 1 time folded	0	0%	**0,002***
	2. Large parts of the gum not mixed	9	30,0%	2. Large parts of the gum not mixed	1	3,3%	
	3. Bolus slightly mixed	13	43,3%	3. Bolus slightly mixed	9	30,0%	
	4. Bolus well mixed but color not uniform	6	20,0%	4. Bolus well mixed but color not uniform	20	66,7%	
40 cycles							
	2. Large parts of the gum not mixed	7	23,3%	2. Large parts of the gum not mixed	0	0%	**0,008***
	3. Bolus slightly mixed	11	36,7%	3. Bolus slightly mixed	0	0%	
	4. Bolus well mixed but color not uniform	10	33,3%	4. Bolus well mixed but color not uniform	22	73,3%	
	5. Bolus perfectly mixed and color uniform	2	6,7%	5. Bolus perfectly mixed and color uniform	8	26,7%	

Table 5. Level of agreement between observers in the analysis of the chewed gum for the mixing ability test purpose. Both observers analyzed in the 5 visual scales after the patients chewed the gum after 5, 10, 20, 30 and 40 masticatory cycles. The level of agreement is classified in weak, moderate, reasonable, substantial and perfect.

Evaluation Period		**Kappa value**	**p**	**Level of agreement***
T1 Pre-operative	5 masticatory cycles	0,526	0,039	Moderate
	10 masticatory cycles	.619	0,02	Substantial
	20 masticatory cycles	.688	0,00	Substantial
	30 masticatory cycles	.706	0,00	Substantial
	40 masticatory cycles	.344	0,02	Reasonable
	Total kappa score	0,650	0,00	Substantial
T2 Post-operative	5 masticatory cycles	.688	.000	Substantial
	10 masticatory cycles	.250	.284	Reasonable
	20 masticatory cycles	.524	.006	Moderate
	30 masticatory cycles	.571	.013	Moderate
	40 masticatory cycles	1	0,00	Perfect
	Total kappa score	0,72	0,00	Substantial

Table 6. OHIP-19 Results. The questions are related to the group of qualitative domains: 1,2,3 Functional limitation; 4, 5, 6,7 Physical Pain; 8 , 9 Psychological discomfort; 10, 11, 12 Physical limitation; 15, 16, 17 Social limitation; 18, 19 – Incapacity/Handicap. Mean results were significative for all the 3 questions on Functional limitation (1, 2 and 3), and for Physical limitation (10, 11, 12), and they were improved in 2 of 4 for Physical pain (5 and 7), and for 1 of 2 for Psychological limitation (14).

Question	**Evaluation Period**	**Mean Results**	**N**	**Standard deviation**	**p**
1. Difficulty chewing	T1 - Pre-operative	2,6667	15	,61721	0,00*
	T2 - Post-operative	1,6667	15	,72375	
	T1 - Pre-operative	2,6667	15	,61721	0,007*

2. Food catching	T2 - Post-operative	2,0000	15	,75593	
3. Dentures not fitting	T1 - Pre-operative	2,6667	15	,61721	0,003*
	T2 - Post-operative	1,8000	15	,77460	
4. Painful aching	T1 - Pre-operative	1,8000	15	,77460	0,09
	T2 - Post-operative	1,4667	15	,63994	
5. Uncomfortable to eat	T1 - Pre-operative	2,2667	15	,45774	0,015*
	T2 - Post-operative	1,7333	15	,88372	
6. Sore spots	T1 - Pre-operative	1,6000	15	,63246	0,67
	T2 - Post-operative	1,6667	15	,61721	
7. Uncomfortable dentures	T1 - Pre-operative	2,4000	15	,63246	0,003*
	T2 - Post-operative	1,7333	15	,88372	
8. Worried	T1 - Pre-operative	2,0667	15	,70373	0,21
	T2 - Post-operative	1,8000	15	,86189	
9. Self-conscious	T1 - Pre-operative	2,2000	15	,86189	0,138
	T2 - Post-operative	1,8000	15	,86189	
10. Avoids eating	T1 - Pre-operative	2,2000	15	,67612	0,028*
	T2 - Post-operative	1,8000	15	,67612	
11. Interrupts meals	T1 - Pre-operative	1,9333	15	,96115	0,014*
	T2 - Post-operative	1,4667	15	,63994	
12. Unable to eat	T1 - Pre-operative	1,6667	15	,72375	0,028*
	T2 - Post-operative	1,2667	15	,45774	
13. Upset	T1 - Pre-operative	1,6667	15	,81650	0,499
	T2 - Post-operative	1,5333	15	,63994	
14. Has been embarrassed	T1 - Pre-operative	1,6667	15	,61721	0,009*
	T2 - Post-operative	1,2667	15	,59362	
15. Avoids going out	T1 - Pre-operative	1,2667	15	,59362	0,271
	T2 - Post-operative	1,0667	15	,25820	
16. Less tolerant of others	T1 - Pre-operative	1,2667	15	,70373	0,33
	T2 - Post-operative	1,1333	15	,51640	
17. Irritable with others	T1 - Pre-operative	1,3333	15	,72375	1
	T2 - Post-operative	1,3333	15	,72375	
18. Unable to enjoy company	T1 - Pre-operative	1,4000	15	,73679	0,055
	T2 - Post-operative	1,0667	15	,25820	
19. Life unsatisfying	T1 - Pre-operative	1,7333	15	,88372	0,271
	T2 - Post-operative	1,5333	15	,74322	

Table 7. Clinical probing depth. Improvement was significative improved in both mesial and in the left lingual surface of the IRPD pillar tooth.

Probing Depht

		Mean	N	Deviation error	p
Right side	T1 Mesial	2,7857	14	,89258	**0,015***
	T2 Mesial	2,2500	14	,47027	
Right side	T1 Distal	1,9231	13	,64051	0,29
	T2 Distal	1,7308	13	,59914	
Right side	T1 Vestibular	1,6786	14	,72343	0,189
	T2 Vestibular	1,4643	14	,49862	
Right side	T1 Lingual	1,6429	14	,74495	0,165
	T2 Lingual	1,3571	14	,49725	
Left Side	T1 Mesial	2,4643	14	,63441	**0,022***

	T2 Mesial	2,1429	14	,53452	
Left Side	T1 Distal	2,0714	14	,82874	0,051
	T2 Distal	1,6786	14	,46439	
Left Side	T1 Vestibular	1,5714	14	,51355	0,082
	T2 Vestibular	1,3571	14	,49725	
Left Side	T1 Lingual	1,8214	14	,54091	**0,005***
	T2 Lingual	1,3214	14	,42095	

Table 8 Supplementary. Measurement off all the collected data from the 15 consecutive patients. Visual analysis from the chewed gum from both observers, Bilateral maximum bite force and clinical probing depth. All the data in preoperative (T1) and 1 to 1.5 year postoperative (T2). RZA and ROD are the observers.

Patient	Chewing Gum - Visual Analysis					Maximum Bite Force					Probing Depth				
	Cycles	T1 RZA	T1 ROD	T II RZA	T II ROD		T1 RS	T1 LS	T2 RS	T2 LS		T1 RS	T1 LS	T2 RS	T2 LS
1															
	5 cycles	1	1	2	2	1º bite	10.50	6.60	8.95	10.95	Mesial	1	1	2	1
	10 cycles	2	2	2	2	2º bite	8.50	16.35	7.25	11.50	Distal	1	1	1	1
	20 cycles	3	2	4	3	3º bite	7.90	14.00	8.45	11.20	Vestibular	1	1	2	1
	30 cycles	3	3	4	4	4º bite	9.75	12.35	8.20	12.20	Lingual	1	2	2	1
	40 cycles	3	4	5	5	5º bite	9.50	14.25	8.30	14.80					
2															
	5 cycles	1	2	2	2	1º bite	4.70	7.30	9.95	6.30	Mesial	3	3	2.5	3
	10 cycles	2	2	3	2	2º bite	6.60	6.10	9.25	8.20	Distal	2	1	2	1
	20 cycles	3	3	3	3	3º bite	9.40	4.80	9.45	6.80	Vestibular	1.5	1	1.5	1
	30 cycles	3	3	3	3	4º bite	5.25	4.55	7.95	6.95	Lingual	1	1.5	1	1.5
	40 cycles	3	4	4	4	5º bite	4.10	2.70	7.75	7.90					
3															
	5 cycles	2	1	2	2	1º bite	1.85	3.75	7.15	8.10	Mesial	2	2	1.5	2
	10 cycles	3	3	2	3	2º bite	2.15	4.20	7.09	7.45	Distal	1	1	1	1.5
	20 cycles	3	3	3	3	3º bite	3.40	3.25	8.35	9.70	Vestibular	1	1	1	1
	30 cycles	4	4	4	4	4º bite	2.80	4.60	8.65	10.25	Lingual	2	1	1	1.5
	40 cycles	4	4	4	4	5º bite	2.30	4.15	5.35	9.20					
4															
	5 cycles	1	1	2	2	1º bite	4.35	8.50	14.60	9.75	Mesial	2	2		
	10 cycles	2	2	4	3	2º bite	3.20	10.95	12.80	10.75	Distal	2	2		
	20 cycles	1	1	2	2	3º bite	3.45	10.35	10.75	9.65	Vestibular	1	2		
	30 cycles	1	1	2	3	4º bite	3.20	9.95	10.50	11.10	Lingual	1	3		
	40 cycles	2	2	4	4	5º bite	4.55	7.95	9.75	11.60					
5															
	5 cycles	1	1	1	1	1º bite	4.65	4.75	7.20	7.35	Mesial	3	2	2.5	2
	10 cycles	2	1	2	2	2º bite	4.85	6.00	6.80	7.25	Distal	2	3	2	2
	20 cycles	3	2	3	2	3º bite	3.50	5.65	6.20	8.45	Vestibular	1	1	1	1
	30 cycles	3	2	4	4	4º bite	5.40	3.90	8.15	9.65	Lingual	1	1	1	1
	40 cycles	4	3	4	4	5º bite	6.15	4.20	7.90	9.80					
6															
	5 cycles	1	1	2	2	1º bite	12.65	11.40	16.60	27.75	Mesial	3	3	3	2
	10 cycles	2	2	3	3	2º bite	19.70	11.40	22.60	28.95	Distal	3	2	2	1
	20 cycles	1	1	4	4	3º bite	17.35	14.05	30.35	29.75	Vestibular	2	1	1	1
	30 cycles	2	2	4	4	4º bite	19.35	10.35	36.80	34.35	Lingual	3	2	1	1
	40 cycles	3	2	5	5	5º bite	19.35	11.90	39.10	36.15					
7															
	5 cycles	2	1	2	2	1º bite	14.05	12.00	13.90	12.80	Mesial	2	2	2	2
	10 cycles	3	2	3	2	2º bite	10.80	11.10	11.70	13.25	Distal	2	2	2	2
	20 cycles	3	3	4	4	3º bite	10.80	8.30	11.45	14.65	Vestibular	1	1	1	1

	30 cycles	4	4	4	4	4º bite	11.90	10.5	9.50	9.65	Lingual	1	1	1	1
	40 cycles	4	5	5	5	5º bite	12.00	10.1	12.20	12.70					
8															
	5 cycles	1	1	1	2	1º bite	2.15	4.20	3.05	4.45	Mesial	2	2.5	2	2
	10 cycles	1	1	2	2	2º bite	2.80	3.50	4.00	4.55	Distal	2	2	1	1
	20 cycles	1	1	2	2	3º bite	3.45	2.25	3.20	3.55	Vestibular	2	2	1	2
	30 cycles	2	2	3	3	4º bite	2.50	2.75	4.15	4.20	Lingual	2	2	2	2
	40 cycles	2	2	4	4	5º bite	2.65	2.80	4.25	3.90					
9															
	5 cycles	1	1	2	2	1º bite	3.50	7.35	5.50	8.40	Mesial	3	3	2	3
	10 cycles	1	1	2	2	2º bite	4.30	7.10	5.55	7.55	Distal	1	2	1.5	2
	20 cycles	2	2	3	3	3º bite	4.10	5.90	5.10	8.95	Vestibular	1	2	1	1
	30 cycles	2	2	3	3	4º bite	2.85	5.90	5.10	8.10	Lingual	1	2	1	1
	40 cycles	3	3	4	4	5º bite	3.90	7.65	6.30	7.60					
10															
	5 cycles	2	2	1	1	1º bite	8.95	10.80	15.50	8.65	Mesial	3	3	2	3
	10 cycles	2	2	3	3	2º bite	8.80	4.20	15.80	10.90	Distal	1	2	1.5	2
	20 cycles	3	3	3	4	3º bite	11.15	6.50	10.70	7.45	Vestibular	1	2	1	1
	30 cycles	3	3	4	4	4º bite	8.65	5.95	9.74	9.00	Lingual	1	2	1	1
	40 cycles	3	4	4	4	5º bite	9.75	7.30	8.25	7.95					
11															
	5 cycles	1	1	2	2	1º bite	5.15	3.40	7.05	10.25	Mesial	5	3	3	2
	10 cycles	1	1	3	3	2º bite	6.10	4.95	8.45	11.05	Distal	3	3	2	2
	20 cycles	2	2	3	3	3º bite	5.50	5.80	10.20	12.05	Vestibular	3	2	2	2
	30 cycles	3	2	4	4	4º bite	6.75	6.10	9.45	13.05	Lingual	1	2	1	2
	40 cycles	2	2	4	4	5º bite	5.30	5.01	10.02	14.05					
12															
	5 cycles	2	2	2	3	1º bite	4.00	4.30	11.40	10.85	Mesial	3	2	2	2
	10 cycles	2	2	2	2	2º bite	3.65	5.50	8.80	12.85	Distal	2	4	3	2
	20 cycles	2	3	3	3	3º bite	3.15	6.0	8.15	14.25	Vestibular	2	2	2	2
	30 cycles	3	3	4	4	4º bite	3.75	6.0	6.20	13.55	Lingual	2	3	2	2
	40 cycles	4	4	4	4	5º bite	3.50	6.0	9.10	10.50					
13															
	5 cycles	1	1	2	2	1º bite	3.60	2.65	6.80	7.80	Mesial	3	2	2	2
	10 cycles	2	1	3	2	2º bite	4.45	4.65	6.30	7.55	Distal	2	2	2	2
	20 cycles	2	2	3	3	3º bite	4.45	3.20	6.45	6.80	Vestibular	2	2	2	1
	30 cycles	3	3	4	3	4º bite	4.10	4.45	6.75	6.80	Lingual	3	2	2	1
	40 cycles	3	3	4	4	5º bite	6.00	4.50	6.25	7.70					
14															
	5 cycles	2	2	3	3	1º bite	14.40	9.15	29.20	25.25	Mesial	3	3	3	2
	10 cycles	2	2	3	3	2º bite	15.30	9.85	28.95	15.00	Distal	2	2	1	2
	20 cycles	3	3	4	3	3º bite	16.20	18.90	32.05	27.70	Vestibular	2	2	2	2
	30 cycles	4	4	4	4	4º bite	11.20	16.30	34.80	29.95	Lingual	2	2	1	1
	40 cycles	4	5	5	5	5º bite	7.50	10.65	34.35	26.10					
15															
	5 cycles	1	1	2	2	1º bite	1.50	1.90	2.95	2.70	Mesial	3	3	2	2
	10 cycles	2	2	2	3	2º bite	2.05	2.85	2.70	3.20	Distal	2	2	2	2
	20 cycles	2	2	3	3	3º bite	2.50	2.50	3.15	2.95	Vestibular	3	2	2	2
	30 cycles	2	3	3	4	4º bite	2.10	2.55	2.95	3.80	Lingual	2	2	2	1.5
	40 cycles	3	3	4	4	5º bite	2.50	2.65	3.30	3.30					

CAPÍTULOS

3.2 CAPÍTULO 2

Artigo ACEITO na Research, Society and Development (RSD Qualis A3 em Odontologia) em 27 / 07 / 2022

Masticatory function evaluation methods: Critical analysis of selected literature

Rafael Zetehaku Araujo DDS, MS[1]

Karla Zancopé DDS, MS, PhD[1]

Rodrigo Silva Moreira DDS[1]

Flávio Domingues das Neves DDS, MS, PhD[1]

[1] Federal University of Uberlândia - UFU, School of Dentistry, Department of Oclusion,

Prosthesis and Dental Material, Uberlândia, Minas Gerais, Brazil.

Corresponding Author:
Dr. Rafael Zetehaku Araujo
Federal University of Uberlândia. Department of Oclusion, Prosthesis and Dental Material
Av. Pará, 1720 - Umuarama, Uberlândia, Minas Gerais, Brazil. Zip Code: 38.405-320
Phone number: +55 73 99922-5570 E-mail: rafaelzaraujo@hotmail.com

ABSTRACT
Objective: To identify the ideal and/or most suitable masticatory function assessment methodology or treatment for each group of patients. **Material and Methods:** A survey was carried out in the MEDLINE, Science Direct, and Embase databases for articles published since 1990. The articles were initially selected by their titles and abstracts, and after application of inclusion and exclusion criteria, some were selected for full text reading. The studies were submitted to qualitative, quantitative, and bias analysis. **Results:** Of the 1,514 studies retrieved in the initial search, 51 were selected for complete analysis. Advantages of the test foods Optocal and Optosil included reliability and standardization capacity, while their disadvantages included high processing time and hardness. Wax was mentioned for its ease of chewing and testing speed, with the disadvantages of handling and the influence of temperature, in addition to low palatability. Chewing gum exhibited a speedy and easy way of testing, low cost, and reliability, in addition to commercial availability. **Conclusion:** Among the existing methodologies, those that were used in few studies or not validated require additional data, and for now, their indication is not recommended. Optocal and Optosil should be indicated for patients who do not have impaired chewing function. Chewing gum is a more suitable test food for patients with impaired chewing. Its practicality in being used in tests and evaluation of results makes it a more comprehensive indicator for different types of patients, treatments, or needs to assess masticatory function.

Key Words: mixing ability; oral function, masticatory performance, chewing, test food

INTRODUCTION

Mastication is a physiological process that involves food fragmentation. Its harmonious performance depends on various structures such as the tongue, teeth and muscles for its proper function (Elsig et al., 2015; Hiiemae, 2004; Tada & Miura, 2017). Satisfactory masticatory function will influence the nutritional status and yield a better quality of life (Elsig et al., 2015; Hiiemae, 2004; Onozuka et al., 2003; Sheiham et al., 2001; Tada & Miura, 2017). Propper masticatory function is so important, that recent studies point to its influence as an activity that protects cognitive function and prevents degenerative diseases of the patient's central nervous system (Elsig et al., 2015; Momose et al., 1997; Okamoto et al., 2010; Onozuka et al., 2003; Sheiham et al., 2001).

Masticatory function can be assessed by masticatory performance and by masticatory efficiency. These terms are also ambiguous and can cause some confusion in the literature, and that may lead to compare different test methods and lead to a misjudgment in the current literature (Gonçalves et al., 2021; Van der Bilt & Fontijn-Tekamp, 2004). Chewing performance refers to the chewing outcome after a determined number of chewing cycles (Gonçalves et al., 2021; Schimmel et al., 2015; Van der Bilt & Fontijn-Tekamp, 2004). Chewing efficiency is referred to the number fo chewing cycles needed to obtain a particular chewing outcome (Gonçalves et al., 2021; Schimmel et al., 2015; Van der Bilt & Fontijn-Tekamp, 2004). Simplifying those terms, chewing performance is an individual's ability to grind solid foods in a certain number of masticatory cycles, and/or masticatory efficiency, which is the number of cycles needed for the test food particles to reach a size suitable for swallowing (Gonçalves et al., 2021; Schimmel et al., 2015; Van der Bilt & Fontijn-Tekamp, 2004). The tests and the methods of evaluation for them are different and must be evaluated separately (Gonçalves et al., 2021).

A person's masticatory function, more specifically, his masticatory performance, can be assessed using a wide variety of natural or artificial “test foods”, chewed through a number of predetermined masticatory cycles to observe the degree of food comminution or fragmentation. The evaluation of the average size of the chewed particles of a test food will determine the results, and it is often carried out using sieving methods (single or multiple) (Gonçalves et al.,

2021; Van der Bilt & Fontijn-Tekamp, 2004). Test foods include those from natural sources, such as carrots, almonds, and coffee beans, and artificial sources, such as Optosil and Optocal (Eberhard et al., 2012; Neves et al., 2015; Schimmel et al., 2015; Vaccaro et al., 2016).

Another way of evaluating masticatory function is the mixing ability test (chewing efficiency), which analyzes an individual's ability to form a cohesive and homogeneous bolus (Asakawa et al., 2005; H. Sato et al., 2003; Van der Bilt & Fontijn-Tekamp, 2004). The mixing ability test index of masticatory function is based on the mixture of color and shape of a given food stuff (Asakawa et al., 2005; H. Sato et al., 2003; S. Sato et al., 2003). This method was validated when compared to the sieving method (H. Sato et al., 2003; S. Sato et al., 2003). For this type of test, some studies used commercial or specially developed chewing gums to analyze mixing ability; others used paraffin cubes, each citing specific advantages over other masticatory function assessment methods (Fueki et al., 2008; Kamiyama et al., 2010; Liedberg & Owall, 1995; Speksnijder et al., 2009). This type of evaluation employs several ways to obtain results, such as software to evaluate the pixels of the formed images, a visual scale, or a colorimetric analysis (Kamiyama et al., 2010; Schimmel et al., 2007; Vaccaro et al., 2016). Other forms of evaluation using gummy jellies, fuchsin capsules, gelatin, and silicone are also cited (Buschang et al., 1997; Escudeiro Santos et al., 2006; Felício et al., 2008; Reitemeier et al., 2012; Tanaka & Shiga, 2018; Yamamoto & Shiga, 2018).

In view of the several different methods and test foods used to evaluate masticatory/chewing performance and chewing efficiency, as well as their respective ways of obtaining or evaluating results. There is still no consensus in the literature on the best method to evaluate masticatory performance or which method should be indicated for a specific group of patients (Gonçalves et al., 2021; Kapur & Soman, 2006). It is thus necessary to distinguish these tests from one another in relation to their main objective and the type of treatment instituted, in addition to the physiological characteristics of the patients under evaluation (Gonçalves et al., 2021; Kapur & Soman, 2006). The objective of this study was to carry out a literature review to identify which masticatory function evaluation tests are currently available, their respective indications, advantages and disadvantages, and their availability and ease of use, with a view to suggest

which test would be more suitable according to the dental condition under evaluation.

MATERIAL AND METHODS

Procedure

The authors selected articles based on the inclusion and exclusion criteria. All potentially eligible studies were analyzed and included. All disagreements were analyzed between members and eliminated through discussion with the researchers, thus leading to a consensus. This research does not have the intent to be a systematic review of the literature, but some specific care so that the most rigorous methodological criteria could be applied to this literature review were taken.

Search strategy

Two independent reviewers (RZA and RSM) conducted an electronic survey of the PubMed/Medline, Science Direct, and Embase databases searching for articles published in English between January 1990 and June 2021. The keywords used were: “masticatory performance”, “masticatory efficiency”, and “masticatory cycle”. A manual search was performed in the following relevant journals in the field within the stipulated period: Clinical Implant Dentistry and Related Research; Clinical Oral Implants Research; International Journal of Oral and Maxillofacial Implants; International Journal of Oral and Maxillofacial Surgery; Journal of Oral and Maxillofacial Surgery; Journal of Periodontology; Journal of Prosthodontics; Journal of Craniofacial Surgery; Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology; and the Journal of Prosthetic Dentistry. All titles were analyzed, and the relevant ones were selected according to the inclusion criteria. Any disagreement between the authors was eliminated.

Study selection criteria

The initial study selection consisted of an analysis of the article title and abstract. Prospective and retrospective studies were both included, given the existence of few randomized controlled studies. Subsequently, eligible studies were analyzed and included or excluded from the total sample. Thus, the population, the intervention, the comparison and the outcome (PICO), as recommended by PRISMA, were determined as a questioning criterion for organization of a clear

clinical question with an appropriate inclusion focus, and although this is not a systematic review of the literature, we tried to follow some of the PRISMA recommendations so that this review could extract reliable results from the included works and evaluated data (29).

Population or participants: Patients subjected to masticatory evaluation who had or had not undergone dental treatment rehabilitation.

Intervention: All methodologies that evaluated masticatory performance or efficiency.

Comparison: Two or more methods of evaluating masticatory performance or efficiency in the same study or in comparison to other studies.

Outcome: To analyze the advantages, disadvantages, reliability and availability/ease of each masticatory performance evaluation method.

Inclusion criteria

A. Studies published since 1990.

B. Studies in English.

C. Studies in humans.

D. Studies with at least five patients evaluated.

E. Studies that conducted the masticatory performance or efficiency test with any researched or available test food, with the masticatory evaluation being the main factor under study

Only studies that offered parameters for comparison between the included/evaluated studies were included.

Exclusion criteria

A. Duplicate studies.

B. Studies related to orthodontic therapy; for example, assessment of masticatory efficiency before and after orthodontic treatment or who underwent orthognatic surgery.

C. Studies related to advanced surgeries such as bone reconstruction and zygomatic implants.

D. Studies whose main focus was prosthetic and/or surgical rehabilitation treatments and not masticatory performance itself.

E. *In vitro* assays and biomechanical studies.

F. Studies that emphasized systemic aspects or pathologies, such as the use of bisphosphonates and osteoporosis, radiotherapy, chemotherapy, and cleft patients.

G. Articles that only focused on prosthesis reconstruction, without elucidating the characteristics of the evaluation of masticatory performance or efficiency.

H. Systematic reviews or reviews that addressed the topic. These studies were used only as theoretical parameters for discussion.

Evaluation of the quality of studies

The evaluation of the quality of the studies was performed using the scale and bias classification of the included studies of the National Health and Medical Research Council (NHMRC) (Commonwealth of Australia©, National Health and Medical Research Council, Melbourne, Australia, https://www.nhmrc.gov.au/sites/default/files/images/appendix-f-levels-of-evidence.pdf). The studies were classified as randomized controlled trial, prospective cohort, or retrospective cohort clinical studies.

Data analysis

Data were obtained following the order: first author, journal and year of publication; bias classification; test food used; number or time of masticatory cycles; type of instituted or compared treatment; dentulous or edentulous patients; number of patients and average age; and result assessment method. When present, information about the advantages and disadvantages of the test food and evaluation method was also collected.

RESULTS

Figure 1 shows the number of articles surveyed, from identification in the databases to quantitative and qualitative analyses. The database search yielded 1,514 articles. After analysis of the titles according to the inclusion and exclusion criteria for duplicate articles, 161 articles were selected for title and abstract reading, of which 81 were excluded. The remaining 80

articles were fully read. Of these 80 articles, 47 were included for the analysis, in addition to 4 other papers searched in specialized journals that were also included. After application of the inclusion and exclusion criteria, 51 articles were selected for complete quantitative and qualitative analysis.

Table 1 presents the detailed information from the analysis of collected data and methodology of selected articles and information described in the methodology used. Author, Year of publication, level of evidence/risk of bias, type of testing food, the number of masticatory cycles used to obtain the results, the type of instituted or compared treatment (and if dentate or edentulous), the number of patients and average age and the form of evaluating the results are all describe in Table 1.

Table 2 presents information about each test food used in the selected articles, specifically in relation to their respective advantages and disadvantages. The evaluation method and data on the type of instituted treatment or evaluated patient and the test food evaluation form are also presented therein.

The main advantages described for the Optocal test food were good reliability and the standardization of its properties (Speksnijder et al., 2009). Nevertheless, this test food still presented some reported disadvantages, such as high time-consuming processing to evaluate the results and difficulty experienced for some participants in chewing, due to its hardness (Molenaar et al., 2012; Speksnijder et al., 2009). The Optosil test food presents the same advantages and disadvantages as Optocal, but Optosil has even greater hardness in chewing specially for patients with impaired masticatory function or tooth loss (Slagter et al., 1993; Van der Bilt et al., 2010).

The only selected article that used Optozeta reported that this test food is both more mechanically stable in the first 7 days and harder compared to Optocal (Khoury-Ribas et al., 2018).

Regarding chewing gum, the main advantages described were related to the ease of being used in evaluation and processing, in addition to being a fast, low-cost, and reliable method (Anastassiadou & Heath, 2001; Schimmel et al., 2015; Van der Bilt et al., 2010). Some chewing

gums are no longer commercialized or have undergone reformulations (Schimmel et al., 2015). Paraffin-based wax was used either in cube or two-colored tablet forms, with the literature reporting its quickness, ease of chewing, and bolus formation as advantages, whereas unpalatability, adherence to prostheses, and the influence of temperature were reported as disadvantages (Asakawa et al., 2005; H. Sato et al., 2003; Speksnijder et al., 2009).

Test methods involving gummy jelly were described as cheap, fast, and easy to perform (Iwashita et al., 2014). In the selected articles, no disadvantage was described.

The main advantage for the group of natural foods was the participants' familiarity and taste with chewing a test food. Its main disadvantage was that standardization of the mechanical properties , making the comparison of results between studies difficult or even impossible (Sugimoto et al., 2012).

The “others” group included different test foods used in only one study or which are no longer available. In addition to these foods having different physical properties, their main disadvantage is difficulty of access.

Table 3 presents the overall information on the methods of assessing masticatory function using a given test food. The form of evaluation, with their specific advantage or disadvantage, according to the studies reviewed is described. The description of the evaluation method and how it is managed is also described. Based on the literature reviewed, some comments and notes of the authors were also included.

The term “gold standard” was used by some authors when applying multiple sieving as a test food evaluation method (Eberhard et al., 2012; Molenaar et al., 2012; S. Sato et al., 2003; Schimmel et al., 2015). Its advantages include reliability and the possibility of both determining the average particle size and comparing inter- and intra-individual results (Eberhard et al., 2012; Molenaar et al., 2012; S. Sato et al., 2003; Schimmel et al., 2015). Also, comminuted particles of the test food selected can be analysed by optical scanning, and the results converted to a particle size distribution (Gonçalves et al., 2021; Van der Bilt & Fontijn-Tekamp, 2004). Its disadvantages include the time necessary for multiple screening, the need for several steps, and the dependence on specific devices such as screens and scales (Van der Bilt & Fontijn-Tekamp,

2004). The cost of this equipment can also be a limiting factor for this type of analysis.

The single sieve method differs from the previous method in that it uses only one sieve with a diameter determined by the average particle size. In general, its advantages and disadvantages are similar to those of multiple sieving, but it is simpler and requires no further statistical analysis, making it more fast and easier than multiple sieves. The main disadvantages when compared to multiples sieves is that it is less detailed, which renders comparisons among individuals more difficult and less reliable (Gonçalves et al., 2021; Van der Bilt & Fontijn-Tekamp, 2004).

On the other hand, digital analysis of images of test foods mixed after chewing can occur through Variance of Hue (VOH), special heterogeneity and optical scanning. The most commom method is with a software that identifies pixels within the image, corresponding to the portions of the test food that were mixed or not (Prinz, 1999; Schimmel et al., 2007; Schimmel et al., 2015; Speksnijder et al., 2009; Van der Bilt et al., 2010). Software used for this purpose was not developed specifically for but rather adapted to this type of evaluation, such as those derived from Adobe Photoshop (Schimmel et al., 2007; Speksnijder et al., 2009). The Viewgum software (ViewGum© software, dHAL Software, Greece, www.dhal.com) was specifically developed to evaluate mixing ability from the digital image obtained through photographing or scanning two-colored chewing gums. Evaluation using such software presents ease, reliability, speed, and low cost as advantages; the need to repeat the acquisition of the image or the reading by the software may pose as disadvantages for this method (Prinz, 1999; Schimmel et al., 2007; Schimmel et al., 2015; Speksnijder et al., 2009; Van der Bilt et al., 2010) [10,19,21,31,37]. The analysis of the mixture of two-colored food stuff or of jelly candies can be performed visually using scales or scores as pre-established parameters , with the advantage of low cost, good reliability, simplicity, and speed (Igarashi et al., 2019; Komagamine et al., 2011; Liedberg & Owall, 1995; Schimmel et al., 2007; Schimmel et al., 2015). Another method described to analyze color changes in test foods was the use of a colorimeter (Aimaijiang et al., 2016; Hama et al., 2014; Kamiyama et al., 2010; Komagamine et al., 2011; Ohira et al., 2012).

There are other devices such as glycosensors (glucose sensor) that can measure the sugar content decrease in the test food used, correlating it with the chewing capacity (Iwashita et al.,

2014; Tanaka & Shiga, 2018; Yamamoto & Shiga, 2018), or spectrophotometers to quantify fuchsin granules, which are currently no longer commercially available (Cazal et al., 2016; Escudeiro Santos et al., 2006; Felício et al., 2008).

DISCUSSION

Over the last decade, the relationship between masticatory function, its systemic benefits, and quality of life has been widely discussed and studied. Some studies have indicated that masticatory performance is one of the most important parameters in relation to the nutritional level and quality of life of elderly patients, while some have reported on the importance of increasing or maintaining masticatory capacity as a favorable factor to healthy aging and preservation of some cognitive functions (Lee et al., 2014; Locker & Grushka, 1987).

This literature review did not include studies that applied only masticatory function evaluation as a way to obtain data after instituting specific dental, prosthesis and/or implant treatments. Only studies that presented a complete, detailed description of the relationship between the results of proposed treatments or specific groups of patients, based on the different methodologies for assessing masticatory function (regardless of which methodology was used) were considered.

The use of a judicious methodology for the selection and evaluation of the articles included in this review allowed us to compare the test foods and their respective forms of evaluation to evaluate the results from the literature published over the last 32 years.

Test foods/materials published in few studies that have clear disadvantages regarding their use, evaluation or standardization or that are not commercially available (such as fuchsin capsules, beads or artificial foods) have not been fully discussed in this review (Buschang et al., 1997; Escudeiro Santos et al., 2006; Felício et al., 2008). Although they might have had good results in their previous studies published, the impossibility of continuous use or comparison does not have clear benefits for the purpose of this literature review (Buschang et al., 1997; Escudeiro Santos et al., 2006; Felício et al., 2008).

Natural foods were used as the first test foods in earlier publications, and were gradually replaced by artificial foods, which have standardized properties (Eberhard et al., 2012; Manly &

Braley, 1950; Sugimoto et al., 2012). The advantage that natural foods present regarding the pleasant taste and the participants' familiarity when chewing does not overcome the disadvantage of non-standardized samples, rendering a comparison of results unfeasible (Eberhard et al., 2012).

Paraffin-based wax cubes have been used in few studies, and although they have advantagens such as low cost and availability; their disadvantages, including the relationship between temperature and hardness of this food stuff, the need to handle samples before they are used, its unpalatability, and its adherence to patients' prostheses, do not justify their use (Asakawa et al., 2005; S. Sato et al., 2003; Speksnijder et al., 2009).

Gummy jellies have been published in several studies, but they have not yet been validated in comparison to other masticatory performance evaluation methods or food tests. Also, their use with defined protocols has not yet been established, making it difficult to interpret results, apply intergroup comparisons, and appraise the factors that may influence outcomes (Komagamine et al., 2019; Tanaka & Shiga, 2018; Uesugi & Shiga, 2017; Yamamoto & Shiga, 2018). The evaluation methods to obtain the results for the gummy jelly’s have not been fully validated and/or compared to other stablished and validated masticatory performance methods. The collection and rinsing, the preparation of the dissolution of the ingredients to evaluate results, make necessary trained personel, making it more difficult to reproduce, to measure and to compare results (Gonçalves et al., 2021). For these reasons, the aforementioned materials should not constitute, nowadays, the first choice in the assessment of masticatory performance.

The most frequently used food test material in the literature are Optosil® (a condensation silicone used in dental moldings), Optocal (the first test food developed exclusively for assessing chewing performance among the included articles), and chewing gums (reported in the largest number of articles to date). The use of Optosil was justified by some authors due to the possibility of determining the sample format and size (not feasible with natural foods), and the ease in standardizing its physical properties, in addition to it not being degraded by saliva (Pocztaruk et al., 2008; Slagter et al., 1993; Van der Bilt et al., 2010; Van der Bilt et al., 1987). Optocal was developed to be a softer test food than Optosil (Slagter et al., 1993; Van der Bilt et

al., 2010) [31,32]. The hardness of Optosil makes it difficult to use it as a test food to assess masticatory performance in individuals with impaired masticatory function, such as patients with full and/or removable dentures, and patients with neuromuscular disorders (Gonçalves et al., 2021; Slagter et al., 1993; Van der Bilt et al., 2010). Optocal is composed of Optosil itself incorporated with other components such as petroleum jelly, alginate powder, plaster powder, and toothpaste, rendering it softer than Optosil. The components used in its preparation need to be carefully dosed in order not to change its mechanical properties. Maybe this might be the biggest limitation among the comminution tests. The importance of choosing the correct population and the food test will directly impact the results of the masticatory performance, specially when trying to compare results from patients with different oral conditions or submitted to different dental reahabilitation (Gonçalves et al., 2021).

Due to the need for preparation and adequate handling of Optocal/Optosil, and the fact that chewing gums are commercially available and therefore readily disponible for use, they are currently used in a greater number of studies to evaluate masticatory performance (Liedberg & Owall, 1995; Schimmel et al., 2015; Silva et al., 2018; Van der Bilt et al., 2010). It is important to emphasize that this methods are mixing ability tests, and some of the studies published tend to quote or compare them with chewing performance methods, and this comparison may lead to bias or misjudgment of results. In general, the use of chewing gums to evaluate mixing ability is justified by the ease of obtaining the test food, the speed and simplicity of the test application, and the reliability and cost of the evaluation method employed (Schimmel et al., 2015; Van der Bilt et al., 2010). The texture and flavor of the gums, as well as the non-adherence to prostheses, are other advantages of this method, thus presenting the same advantages as natural food stuffs (Silva et al., 2018). Their quick and simple assessment make them available for different professional environments such as dental offices, hospitals, psychiatric and geriatric wards. In regard to the number of cycles needed, most of the studies published have different chewing cycles employed in their methodologies. The literature tends to suggest that 20 chewing strokes have the vest discriminatory characteristics to compared patients and treatments (Gonçalves et al., 2021).

The form of processing and obtaining the results of the selected test food to evaluate masticatory performance is a key factor and must be carefully considered when determining the choice of test material. It is thus important to know how the chosen processing takes place, its advantages, and its possible limitations. In fragmentation tests, which is the case with Optosil and Optocal, the most commonly used result processing form is multiple sieving as it constitutes a very reliable method (Van der Bilt & Fontijn-Tekamp, 2004). However, the number of studies employing screening methods as an initial choice decreased mainly due to the large number of steps necessary for its processing and the need to have a specific scale and sieves. The time consuming and the costs of the sieving methods are high when compared to some of the other available methods. Also, comminution tests are sensitive to changes in bite force, dental state and other possible oro-facial system changes, making it not suitable for all types of patients (Gonçalves et al., 2021). All these advantages and disadvantages and comparison are listed in Table 3. The analysis of mixing ability can occur in several different ways, with digital or visual methods (Halazonetis et al., 2013; Schimmel et al., 2015; Silva et al., 2018; Van der Bilt et al., 2010). The method of processing chewing gums (currently, software specific to this purpose) has been one of the greatest advantages of using this material (Halazonetis et al., 2013; Schimmel et al., 2015). Such software programs have been validated in the literature and present reliable, easy, and quickly measurable results (Schimmel et al., 2015; Silva et al., 2018). Due to their practicality, low cost, and fast results, chewing gums are presently the most used test food to evaluate masticatory performance, and have been suggested for research on large populations (Liedberg & Owall, 1995; Schimmel et al., 2007). It is worth mentioning that the limits of this test are not yet known in relation to different types of dentition.

The articles selected in this literature review varied between satisfactory or poor after assessment of the risk of bias according to the NHMRC scale, so their results should be interpreted with caution. In view of the various test foods and forms of processing available to assess masticatory function, each with its specific advantages and disadvantages, it is suggested that the ideal evaluation method has yet to be fully developed or standardized, especially when we thing in a universal method of evaluation that might be suitable to perform

to individual groups of patients or treatments, and possibly to compare them. The standardization or adequacy of masticatory function evaluation will allow great evolution in understanding the importance of mastication and its impact on a patient's systemic health. It is imperative to understand the differences and indications among the evaluation methods of chewing performance and chewing efficiency.

Our results showed Optocal and Optosil) were used more in studies with participants who present high chewing performance (patients with implants or patients with complete normal dentition). We suggest after this extensive and critical review of the literature that comminution tests (with Optosil and Optacal and evaluated through multiple sieving methods) may be used only for this "group" of patients and should no be indicated to patients with impaired oral conditions or diminished masticatory function. They are very reliable and can be used to compared treatments outcomes (before and after). Chewing ability, evaluated mostly by mixing ability tests, and in this case, with commercially gums evaluated by open and free software's, are more suitable and should be the first choice for patients with total or partial removable prostheses, elderly patients (with reduced masticatory muscle strength), children, geriatric patients, patients with neurological disturbances or any other oral disfunction, such as after ressective oral surgeries. In an attempt to standardize masticatory performance evaluation methods, especially in clinical, hospital and research settings that evaluate patients with age-deficient chewing, edentulism or systemic changes, the use of chewing gum seems to be the most indicated procedure for its practicality, low cost, reproducibility, and easy results. Also, to obtain epidemiological data and evaluate large samples of population they are more suitable. It should be noted that the protocols for using chewing gum for each patient profile still need to be further explored, and that additional studies are needed to identify which factors can influence the physical properties of commercially available chewing gums and consequently alter their results.

CONFLICT OF INTEREST

None declared.

REFERENCES

Aimaijiang, Y.; Otomaru, T. & Taniguchi, H. (2016). Relationships between perceived chewing ability, objective masticatory function and oral health-related quality of life in mandibulectomy or glossectomy patients with a dento-maxillary prosthesis. *Journal of Prosthodontic Research*, 60(2), 92–97.

Anastassiadou, V. & Heath, M. R. (2001). The development of a simple objective test of mastication suitable for older people, using chewing gums. *Gerodontology*, *18*(2), 79-86.

Asakawa, A.; Fueki, K. & Ohyama, T. (2005). Detection of improvement in the masticatory function from old to new removable partial dentures using mixing ability test. *Journal of Oral Rehabilitation*, 32(9), 629-634.

Buschang, P. H.; Throckmorton, G. S.; Travers, K. H. & Johnson, G. (1997). The effects of bolus size and chewing rate on masticatory performance with artificial test foods. *Journal of Oral Rehabilitation*, 24(7), 522-526.

Cazal, M. S.; da Silva, A. M.; Galo, R.; Junior, W. M. & da Silva, M. A. (2016). Comparison of dynamic electromyographic analysis of masticatory capsules with materials of different textures. *Cranio*, 34(2), 105-111.

Eberhard, L. et al. (2012). Comparison of particle-size distributions determined by optical scanning and by sieving in the assessment of masticatory performance. *Journal of Oral Rehabilitation*, 39(5), 338-348.

Elsig, F. et al. (2015). Tooth loss, chewing efficiency and cognitive impairment in geriatric patients. *Gerodontology*, 32(2), 149-156.

Escudeiro Santos, C.; de Freitas, O.; Spadaro, A. C. & Mestriner-Junior, W. (2006). Development of a colorimetric system for evaluation of the masticatory efficiency. *Brazilian Dental Journal*, 17(2), 95-99.

Felício, C. M.; Couto, G. A.; Ferreira, C. L. & Mestriner Junior, W. (2008). Reliability of masticatory efficiency with beads and correlation with the muscle activity. *Pro Fono Revista de Atualização Científica*, 20(4), 225-230.

Fueki, K.; Sugiura, T.; Yoshida, E. & Igarashi, Y. (2008). Association between food mixing ability and electromyographic activity of jaw-closing muscles during chewing of a wax cube. *Journal of Oral Rehabilitation*, 35(5), 345-352.

Gonçalves, T. M. S. V. et al. (2021). Consensus on the terminologies and methodologies for masticatory assessment. *Journal of Oral Rehabilitation*, 48(6), 745-761.

Halazonetis, D. J.; Schimmel, M.; Antonarakis, G. S. & Christou, P. (2013). Novel software for quantitative evaluation and graphical representation of masticatory efficiency. *Journal of Oral Rehabilitation*, 40(5), 329-335.

Hama, Y.; Kanazawa, M.; Minakuchi, S.; Uchida, T. & Sasaki, Y. (2014). Properties of a color-changeable chewing gum used to evaluate masticatory performance. *Journal of Prosthodontic Research*, 58(2), 102-106.

Hiiemae, K. (2004). Mechanisms of food reduction, transport and deglutition: how the texture of food affects feeding behavior. *Journal of Texture Studies*, 35(2), 171-200.

Igarashi, K. et al. (2019). Validity of a visual scoring method using gummy jelly for evaluating chewing efficiency in a large-scale epidemiological survey. *Journal of Oral Rehabilitation*, 46(5), 409-416.

Iwashita, H. et al. (2014). Comparative cross-sectional study of masticatory performance and mastication predominance for patients with missing posterior teeth. *Journal of Prosthodontic Research*, 58(4), 223-229.

Kamiyama, M.; Kanazawa, M.; Fujinami, Y. & Minakuchi, S. (2010). Validity and reliability of a Self-Implementable method to evaluate masticatory performance: use of color-changeable chewing gum and a color scale. *Journal of Prosthodontic Research*, 54(1), 24-28.

Kapur, K. K. & Soman, S. D. (2006). Masticatory performance and efficiency in denture wearers. 1964. *The Journal of Prosthetic Dentistry*, 95(6), 407-411.

Khoury-Ribas, L.; Ayuso-Montero, R.; Rovira-Lastra, B.; Peraire, M. & Martinez-Gomis, J. (2018). Reliability of a new test food to assess masticatory function. *Archives of Oral Biology*, 87, 1-6.

Komagamine, Y.; Kanazawa, M.; Minakuchi, S.; Uchida, T. & Sasaki, Y. (2011). Association between masticatory performance using a colour-changeable chewing gum and jaw movement. *Journal of Oral Rehabilitation*, 38(8), 555-563.

Komagamine, Y.; Kanazawa, M.; Sato, D. & Minakuchi, S. (2019). A preliminary comparison of masticatory performances between immediately loaded and conventionally loaded mandibular two-implant overdentures with magnetic attachments. *Clinical Implant Dentistry and Related Research*, 21(1), 130-137.

Lee, I. C.; Yang, Y. H. & Ho, P. S. (2014). Chewing ability, nutritional status and quality of life. *Journal of Oral Rehabilitation*, *41*(2), 79-86.

Liedberg, B. & Owall, B. (1995). Oral bolus kneading and shaping measured with chewing gum. *Dysphagia*, 10(2), 101-106.

Locker, D. & Grushka, M. (1987). Prevalence of oral and facial pain and discomfort: preliminary results of a mail survey. *Community Dentistry and Oral Epidemiology*, 15(3), 169-172.

Manly, R. S. & Braley, L. C. (1950). Masticatory performance and efficiency. *Journal of Dental Research*, 29(4), 448-462.

Molenaar, W. N. et al. (2012). The effect of food bolus location on jaw movement smoothness and masticatory efficiency. *Journal of Oral Rehabilitation*, 39(9), 639-647.

Momose, T. et al. (1997). Effect of mastication on regional cerebral blood flow in humans examined by positron-emission tomography with 15O-labelled water and magnetic resonance imaging. *Archives of Oral Biology*, 42(1), 57–61.

Neves, F. D. et al. (2015). Masticatory performance with different types of rehabilitation of the edentulous mandible. *Brazilian Journal of Oral Sciences*, 14(3), 186-189.

Ohira, A.; Ono, Y.; Yano, N. & Takagi, Y. (2012). The effect of chewing exercise in preschool children on maximum bite force and masticatory performance. *International Journal of Paediatric Dentistry*, 22(2), 146-153.

Okamoto, N. et al. (2010). Tooth loss is associated with mild memory impairment in the elderly: the Fujiwara-kyo study. *Brain Research*, 1349, 68-75.

Onozuka, M. et al. (2003). Age-related changes in brain regional activity during chewing: a functional magnetic resonance imaging study. *Journal of Dental Research*, 82(8), 657-660.

Pocztaruk, R. e. L.; Frasca, L. C.; Rivaldo, E. G.; Fernandes, E. e. L. & Gavião, M. B. (2008). Protocol for production of a chewable material for masticatory function tests (Optocal - Brazilian version). *Brazilian Oral Research*, 22(4), 305-310.

Prinz, J. F. (1999). Quantitative evaluation of the effect of bolus size and number of chewing strokes on the intra-oral mixing of a two-colour chewing gum. *Journal of Oral Rehabilitation*, 26(3), 243-247.

Reitemeier, B. et al. (2012). Clinical test of masticatory efficacy in patients with maxillary/mandibular defects due to tumors. *Onkologie*, 35(4), 170-174.

Sato, H. et al. (2003). A new and simple method for evaluating masticatory function using newly developed artificial test food. *Journal of Oral Rehabilitation*, 30(1), 68-73.

Sato, S. et al. (2003). Validity and reliability of a newly developed method for evaluating masticatory function using discriminant analysis. *Journal of Oral Rehabilitation*, 30(2), 146-151.

Schimmel, M.; Christou, P.; Herrmann, F. & Müller, F. (2007). A two-colour chewing gum test for masticatory efficiency: development of different assessment methods. *Journal of Oral Rehabilitation*, 34(9), 671-678.

Schimmel, M. et al. (2015). A novel colourimetric technique to assess chewing function using two-coloured specimens: Validation and application. *Journal of Dentistry*, 43(8), 955-964.

Sheiham, A. et al. (2001). The relationship among dental status, nutrient intake, and nutritional status in older people. *Journal of Dental Research*, 80(2), 408-413.

Silva, L. C.; Nogueira, T. E.; Rios, L. F.; Schimmel, M. & Leles, C. R. (2018). Reliability of a two-colour chewing gum test to assess masticatory performance in complete denture wearers. *Journal of Oral Rehabilitation*, 45(4), 301-307.

Slagter, A. P.; Bosman, F. & Van der Bilt, A. (1993). Comminution of two artificial test foods by dentate and edentulous subjects. *Journal of Oral Rehabilitation*, 20(2), 159-176.

Speksnijder, C. M.; Abbink, J. H.; van der Glas, H. W.; Janssen, N. G. & van der Bilt, A. (2009). Mixing ability test compared with a comminution test in persons with normal and compromised masticatory performance. *European Journal of Oral Sciences*, 117(5), 580-586.

Sugimoto, K. et al. (2012). New image analysis of large food particles can discriminate experimentally suppressed mastication. *Journal of Oral Rehabilitation*, 39(6), 405-410.

Tada, A. & Miura, H. (2017). Association between mastication and cognitive status: A systematic review. *Archives of Gerontology and Geriatrics*, 70, 44-53.

Tanaka, Y. & Shiga, H. (2018). Masticatory performance of the elderly as seen from differences in occlusal support of residual teeth. *Journal of Prosthodontic Research*, 62(3), 375-378.

Uesugi, H. & Shiga, H. (2017). Relationship between masticatory performance using a gummy jelly and masticatory movement. *Journal of Prosthodontic Research*, 61(4), 419-425.

Vaccaro, G.; Pelaez, J. I. & Gil, J. A. (2016). Choosing the best image processing method for masticatory performance assessment when using two-coloured specimens. *Journal of Oral Rehabilitation*, 43(7), 496-504.

Van der Bilt, A. & Fontijn-Tekamp, F. A. (2004). Comparison of single and multiple sieve methods for the determination of masticatory performance. *Archives of Oral Biology*, 49(3), 193-198.

Van der Bilt, A.; Mojet, J.; Tekamp, F. A. & Abbink, J. H. (2010). Comparing masticatory performance and mixing ability. *Journal of Oral Rehabilitation*, 37(2), 79-84.

Van der Bilt, A.; Olthoff, L. W.; van der Glas, H. W.; van der Weelen, K. & Bosman, F. (1987). A mathematical description of the comminution of food during mastication in man. *Archives of Oral Biology*, 32(8), 579-586.

Yamamoto, S. & Shiga, H. (2018). Masticatory performance and oral health-related quality of life before and after complete denture treatment. *Journal of Prosthodontic Research*, 62(3), 370-374.

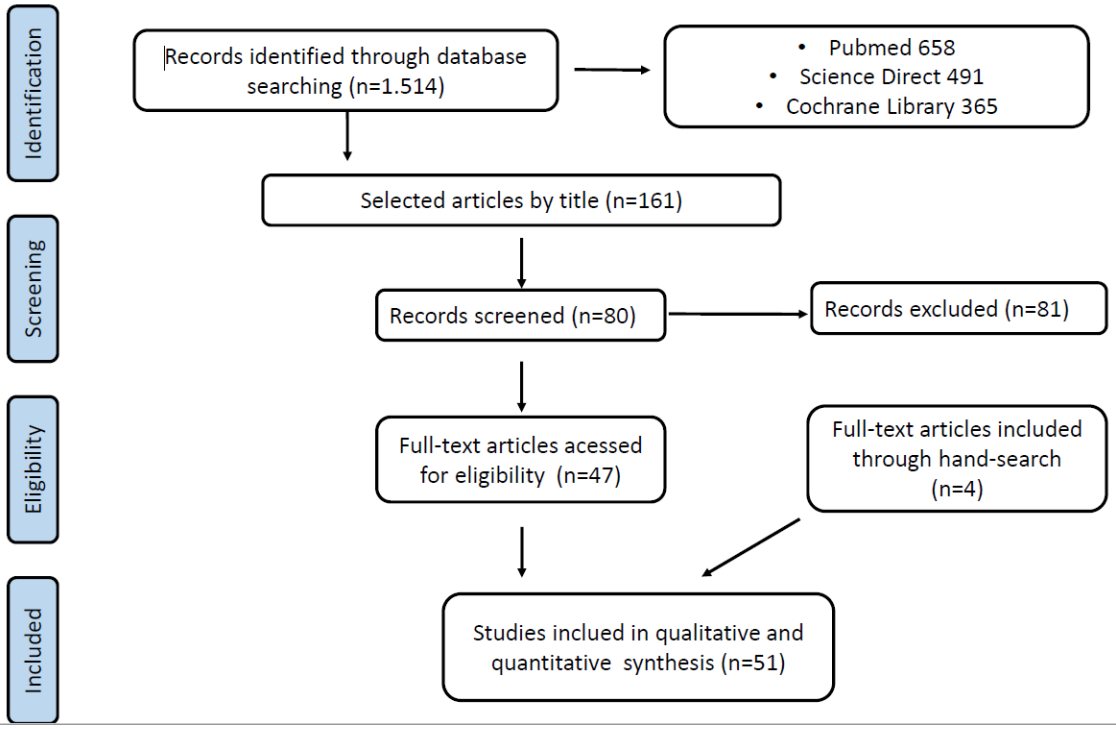


Figure 1. Flowchart

Table 1 – Data and methodology of selected articles.

Author Year	Level of Evidence NHMRC	Testing food	Number of cycles	Type of instituted or compared treatment (dentate or edentulous)	Number of patients and average age	Form of evaluating the results
Slagter[32], 1993	III – 2	Optocal; Optosil	10 (Optocal, only for the dentate group), 20, 40, 60 and 80 MC	ND; CD	n=14; mean 58 years	Sieving
Fontijn-Tekamp[53], 2000	III – 2	Optocal Plus	5,10,20,40 e 60 MC	ND; Partially dentate; OD; CD	"Implants": n=40, mean 58,3 years; "Root-overlay": n=19, mean 59,7 years; "Low bone height": n=13, mean 59 years; "High bone height": n=13, mean 59 years; "Shortened arch": n=14, mean 58,1 years; "Complete arch": n=14, mean 54,1 years; "Complete arch": n=19, mean 22,7 years	Sieving
Van der Bilt[8], 2004	III – 3	Optocal Plus	15 MC	ND (some presented posterior losses)	n=176: 123W and 53M; mean 42,1 and 44,9 years, respectively	Multiple and single sieve method (comparison)
Speksnijder[19], 2009	III – 2	Bi-colored wax cube; Optocal Plus	Wax 5, 10, 15, e 20 MC; Optocal 15 MC	ND; CD upper, OD lower; CD	n=60: 10W and 10M, mean 58,2 years; 9W and 11M, mean 62,2 years; 10W and 10M, mean 60,5 years	Adobe Photoshop software, CS3 extended to the evaluate the wax; Sieving method for the Optocal
Van der Bilt[31], 2010	III – 2	Optosil; Optocal; Chewing Gum	Optocal and Optosil: 15 MC (only for the young group);	ND; PT	n=40: 15w and 5M, mean 72,1 years (elderly); 14W e 6M, mean 24,0 years (young)	Software ADOBE PHOTOSHOP CS2, version 9.0§, to evaluate the gum;

			Chewing gum: 10, 20 MC			Sieving for the Optocal and Optosil
Neves[13], 2015	III - 2	Optocal	40 MC	ND; fixed implant prosthesis upper and lower; fixed implant prosthesis upper, CD lower; CD upper, OD lower; CD	n= 15 aged 20-28; n= 8 aged 55-80; n= 14 aged 55-80; n= 16 aged 30-76; n= 16 aged 30-76	Sieving
Miranda[54], *2019*	III – 3	Optocal	Until they felt the desire to swallow	CD OD	n=40: 27W and 13M, mean 66,2 years	Multiple sieving
Eberhard[12], 2012	IV	Optosil Comfort	15 MC	ND	n=20: 10W and 10M, mean 24 years	Sieving; Particle analysis by scanning and processing in the software (Image J 1.42q; Wayne Rasband, National Institutes of Health, MD, USA.)
Rovira-Lastra[55], 2014	IV	Optosil	20 MC	ND	n=42: 23W and 19M, mean 26,8 years	Sieving
Khoury-Ribas[33], 2018	IV	Optosil Optozeta	20 MC	ND; RPD, CD; IPP	n=35: 23W and 12M, mean 37 years; Retest with n=15: 11W e 4M, mean 34 years	Sieving

Liu[56], 2018	IV	Optosil	3, 7, 14, 28 MC for the whole cube and half of the cube (with 9 cubes per test); 2, 3, 7, 14 MC for half cube (with 4 cubes per test); 1, 2, 3, 7 MC for half cube (with 2 cubes per test)	ND	n=8: 4W and 4M, mean 23,6 year	Sieving
Liedberg[17], 1995	III – 2	Chewing gum developed from SOR-BITS® (A/S Alfred Benzon, Copenhagen)	GA: 10, 20, 40, 60, 80, 100 MC GB: 10 MC	ND; CD; RPD; Absences without prosthetic rehabilitation	GA- n=25: 20W and 5M, aged 32-82 years; GB- n=20 The article does not cite the age this group	Visual analysis of the mixing ability, with score from 1 to 5 according to the scale made by the author
Prinz[37], 1999	IV	Chewing gum Bubble YumTM®	5, 20, 30 MC	ND	n=10: 3W and 7M; The article does not cite the age	Digital image analysis through "Graphics Unbiased Measurement System (GUMS)"
Anastassiadou[34], 2001	III - 2	4 chewing gums: Freedent; Dentine-Ice; Elma-f; Pita	5, 10, 20, 30 MC	ND; CD	n=8: G CD: n=5 aged 58-76 years; G ND: n=3 aged 26-42 years (The author does not cite neither the gender nor the average age)	A formula is applied to check the weight loss of the gum in three moments and relate to the masticatory performance
Schimmel[21], 2007	IV	Chewing gum Hubba-Bubba Tape Gums of two flavors and colors (blue and pink) united	5, 10, 20, 30 e 50 MC	ND	n=20: 11W and 9 M, mean 27,5 years	Visual analysis with score from 1 to 5 (of non-flattened gum); Software Adobe Photoshop Elements 2.0®

Kamiyama[1][8], 2010	IV	Chewing gum xylitol that changes color when chewed	20, 40, 60, 80, 100, 120, 140, 160, 180, 200 MC at a speed of 1 cycle per minute	ND	n=11 for scale calibration phase; n=18 examiners to perform visual analysis of the gum	Colorimeter (CR-13; Konica-Minolta, Tokyo, Japan); Visual scale
Komagamine[57], 2011	IV	Chewing gum xylitol that changes color when chewed	20, 40, 60, 80, 120, 160 MC	ND	n=45: 22W and 23M, mean 29,8 years	Colorimeter; Visual scale
Ohira[40], 2011	III – 2	Chewing gum xylitol that changes color when chewed	2 minutes of mastication	ND	n=70: 34W and 36M, mean 5,4 years n=28: 14W and 14M, mean 5,3 years	Colorimeter (CR-13; Konica-Minolta, Tokyo, Japan)
Molenaar[30], 2012	IV	Chewing gum Hubba-Bubba Tape Gums Goma (azure and White)	Anterior: 20 MC; Posterior: 20 MC	ND	n=10: 4W and 6M, mean 30,3 years	Software Adobe Photoshop Elements 2.0‡, to evaluate the gum
Halazonetis[52], 2013	III – 3	Chewing gum Hubba-Bubba Tape Gums of two flavors and colors (blue and pink) united	5, 10, 20, 30 e 50 MC	ND	n=20: 9W and 11M, mean 27,5 years	Software (ViewGum® software, dHAL Software, Greece, www.dhal.com)
Hama[41], 2014	III – 2	Chewing gum xylitol that changes color when chewed	Calibration: 20, 40, 60, 80, 100, 120, 160, 200 MC; Test: 100 MC	ND; CD	G ND - n=42, mean 26,8 years; G CD - n=47, mean 74,9 years	Colorimeter (CR-13; Konica-Minolta, Tokyo, Japan)
Aimaijiang[42], 2015	III – 3	Chewing gum xylitol that changes color when chewed	100 MC	Removable dentures of patients who underwent	n=38: 18W and 20M, mean 69 years	Colorimeter

				mandibulectomy or glossectomy		
Schimmel[10], 2015	III – 2	3 chewing gums: Hubba-Bubba Tape Gum; LotteTM; Vividen Fruitswing Karpuz/Asai Uzumu	5, 10, 20, 30, 50 MC	ND; CD upper, OD lower	n=20: 10W and 10M, mean 30,3 years n=15: 10W and 5M, mean 74,6 years	Software (ViewGum® software, dHAL Software, Greece, www.dhal.com) Visual analysis with score from 1 to 5
Vaccaro[11], 2016	IV	Chewing gum Trident® of two colors and flavors united (red and white)	3, 6, 9, 12, 15, 18, 21, 25 MC	ND	n=250: 130W and 20M, mean 25 years	Software MATLAB (MPAT V10, Perceptodent Project, University of Malaga, Spain, http://perceptodent.lcc.uma.es) to evaluate the gum
Elmoula[58], 2017	IV	Chewing gum (does not cite the gum brand)	20 MC	CD	n=58: 21W and 37M, mean 61,59 years	Software (Adobe Photoshop CS5; Adobe Systems Inc) to evaluate the gum
Silva[51], *2018*	III – 3	Chewing gum Vividen Fruitswing Karpuz/Asai Üzümü	5, 10, 20, 30, 50 MC	CD	n=75: 51W and 24M, mean 67,1 years	Software (ViewGum® software, dHAL 0Software, Greece, www.dhal.com) Visual analysis with score from 1 to 5
Vaccaro[59], 2018	III – 2	Chewing gum Trident® of two colors and flavors united (red and white)	G1: 0, 5, 10, 15, 20 MC; G2: 20 MC	ND (G1); CD (G2)	n=120 G1- 41W and 39M, mean 25 years; G2- 21W and 19M, mean 73 and 71 years respectively	S Formula-based system for the calculation of the index mix to gums

Nogueira[60], *2018*	III - 3	Chewing gum Vivident Fruitswing Karpuz/Asai Üzümü	20, 50 MC	ND; CD upper, OD lower above one implant	n=34 G OD: n=15; G CD: n=19; 23W and 11M, mean 63.9 years	Software (ViewGum® software, dHAL 0Software, Greece, www.dhal.com)
Komagamine[47], *2018*	III – 1	Chewing gum xylitol that changes color when chewed; gummy jelly	Chewing gum: 60 MC; Gummy jelly: 30 MC	OD lower immediate loading; OD lower conventional loading	n=19: Group immediate: n=10; Group conventional: n= 9; 10W and 9M, mean 68,4 years	Colorimeter (CR-13; Konica-Minolta Sensing, Tokyo, Japan); Visual analysis with score to evaluate the gummy jelly
Iwaki[61], 2019	III – 3	Chewing gum xylitol that changes color when chewed	100 MC	Lower CD that started to use OD on two implants (some used CD upper and other RPD upper)	n=19, mean 69.8	Colorimeter (CR-13; Konica-Minolta Sensing, Tokyo, Japan)
Leles[62], *2019*	IV	Chewing gum Vivident Fruitswing Karpuz/Asai Üzümü	20, 50 MC	CD	n=204: 138W and 66M, mean 65.6 years	Software (ViewGum, dHAL Software, www.dhal.com)
Yousof[63], *2019*	IV	Chewing gum developed from Glee Gum	3,6,9,15 e 25 MC three times	ND	n=20: 10W and 10M, mean 20,9 years	Software (ImageJ 1.51m; US National Institutes of Health); Formula to calculate loss of gum hardness and mass
Sato[14], 2003	III – 2	Bicolored wax cube at 37°C	MC among 5 and 50 chews	ND; RPD upper, ND lower; ND upper, RPD lower;	n=37 G ND: 8W and 13M, mean 29,3 years; G rehabilitated: 9W and 7M, mean 58,8 years	Software (Luzex-FS)‡ to evaluate the photographed wax cube, dividing the groups in "good, medium or bad"

				RPD upper and lower; CD upper, ND lower; RPD upper, CD lower; CD		
Sato[16], 2003	III - 2	Bicolored wax cube; Grains of a test food composed by vegetable oil, fat, carnauba wax	5, 7, 10, 15, 20 and 30 MC, where the dentate chewed on the usual side and the prosthesis users chewed on the edentulous side	ND (A); RPD, ND (B); RPD upper and lower (C)	n=44 GA: 4W and 7M, mean 26,0 years; GB: 18W and 2M, mean 62,6 years; GC: 8W and 5M, mean 66,6 years	Digital analysis of the photographed wax after chewing; Digital analysis of the grains after sieving
Asakawa[15], 2005	III – 3	Bicolored wax cube	10 MC	RPD	n=32: 25W and 7M, mean 65 years	Software (Luzex-FS)[§]
Yoshida[64], 2007	IV	Bicolored wax cube at 37°C	10 MC	ND	n=26: 13W and 13M, mean 25,3 years	Software (Luzex-FS)[§]
Fueki[20], 2008	IV	Bicolored wax cube at 37°C	10 MC	ND	n=20: 10W and 10M, mean 24,1 years	Scanned image and software + calculation using a formula
Fueki[65], 2009	IV	Bicolored wax cube at 37°C; Peanut	Wax: 10 MC; Peanut: 20 MC	ND	n=20: 10W and 10M, mean 24,1 years	Unable to clearly identify how the author processed the results
Iwashita[35], 2014	III – 2	Gummy jelly	20 seconds on each side and free mastication	ND; Unilateral posterior absences; Bilateral posterior absences (they did not use RPD)	n=83: 15W and 15M, mean 26,9 years; 19W and 11M, mean 63,8 years; 18W and 5M, mean 69,2 years	Glucose measuring sensor (Glucosensor GS-1, GC Corporation, Tokyo, Japan)

Uesugi[48], 2017	IV	Gummy Jelly	20 seconds	ND	n=30M, mean 27,4 years	Glucose measuring sensor (GS-1; Fujita, Tokyo, Japan)
Tanaka[22], 2018	III – 3	Gummy jelly	20 seconds	No posterior; Until 1st pre; Until 2nd pre; Until 1st molar; Until 2nd molar	n=149W; mean 72,3 years G1 n=29, mean 76.9years; G2 n=21 mean 71.6years; G3 n=24 mean 72.4 years; G4 n=28 mean 70,4 years; G5 n=47 mean 70,9 years respectively	Glucose measuring sensor (GS-2; GC, Tokyo, Japan)
Yamamoto[23], 2018	IV	Gummy Jelly	20 seconds	CD	n=30: 15W and 15M, mean 74,7 years	Glucose measuring sensor (GS-2; GC, Tokyo, Japan)
Igarashi[39], *2018*	IV	Gummy Jelly	30 MC	CD	n=1248: 742W and 506M Age not specified	Visual analysis with score from 1 to 5; Photoreceptor analysis (As One, Osaka, Japan)
Kapur[28], 2006	IV	Carrots and peanuts	Carrot: 40 MC; Peanut: 20 MC (for calibration, 10 participants chewed carrot for 5, 10, 20, 40, 60, 80, 100 MC)	CD	n=140 Age and gender not specified	Sieving (5 sieves for the carrot and 10 for the almonds)
Sugimoto[36], 2012	IV	Raw carrot, peanuts and beef	Until they felt the desire to swallow and the number of cycles was recorded	ND	n=20W, mean 23,4 years	Software digital image analysis and then sieving
Cazal[43], 2015	IV	Fuchsin capsules; Raisins; Peanut;	For 15 seconds in each side separately	ND	n=30: 15W and 15M, mean 23,46 years	Spectrophotometer (Beckman Inc., Palo Alto, CA, USA).

		Trident® Chewing gum (for electromyography)				
Buschang[27], 1997	IV	CutterSil® Silicone	20 MC; 40 cycles/minute, 100 cycles/minute of speed	ND	n=20M ("young") The article does not cite the age	Sieving
Santos[25], 2006	IV	Fuchsin capsules	20 seconds of mastication	ND (3 of them wore a fixed orthodontic appliance)	N=10: 5W and 5M, aged 25-30 years	Spectrophotometer (Beckman Inc., Palo Alto, CA, USA).
Felício[24], 2008	IV	Fuchsin capsules	20 seconds on each side and free mastication	ND	N=19: 10W and 9M, mean 22,9 years	Spectrophotometer (Beckman Inc., Palo Alto, CA, USA).
Reitemeier[26], 2012	III - 2	Gelatin based cylinder	30 MC	ND; CD; Maxillofacial prosthesis after maxillectomy or mandibulectomy	N=60: 18W and 2M, mean 27 years; 9W and 11M, mean 72 years; 11W and 9M, mean 62 years	Sieving

CD: complete denture; **IPP:** Implant partial prothesis; **M**: Men; **MC:** Masticatory cicle; **n**: number of participants; **ND:** Natural dentition; **OD:** overdenture; **RPD:** removable partial denture; **W:** Woman

Table 2 – Information about the testing food

FOOD	ADVANTAGE	DISADVANTAGE	INDICATION FOR THE PATIENT	FORM OF EVALUATION
Optocal	Reliable, standardizable properties, does not suffer from saliva action	Takes a long time, hard, it takes work to capture all the particles, cannot be stored for long after setting time	ND, upper and lower CD, upper CD and lower OD, lower and upper OD	Sieving

Optosil	Comfortable to chew, reliable, does not suffer from saliva action	Takes a long time, hard, more expensive than other methods, it takes work to capture all the particles, cannot be stored long after setting time	ND, upper and lower CD	Sieving or scanning
Optozeta	More stable than Optocal in the first seven days	Harder, takes a long time, cannot be stored long after setting time	ND, RPD, CD and implant supported RPD	Sieving
Chewing-gum	Fast, does not stick to the prosthesis, easy, inexpensive, easy to store, non-toxic if swallowed, reliable	Need to repeat some scans, suffers from saliva action, may be too soft for dentate patients, may undergo constant reformulations	ND, upper and lower CD, lower OD	Colorimeter, specific software (Viewgum), software that evaluates pixel, visual evaluation, color chart, sugar extraction (weighing the gum)
Wax	Fast, easy to chew, forms a bolus,	Temperature may influence	ND, upper and lower CD, lower OD with upper CD	Software that evaluates pixel
Gummy Jelly	Inexpensive, objective results, easy and fast	Suffers from action of saliva	ND, posterior losses, upper and lower CD	Glucose extraction (glucose sensor)
Natural foods (carrot, almond, steak, raisins)	The patient is familiar with the food	May suffer from saliva action, may be retained or swallowed, lack of food standardization	ND	Sieving or photography of the masticated particles
Others (CutterSil Silicone, RTV silicone, gelatin based cylinder, fuchsin capsules)	Does not absorb saliva, non-toxic, neutral taste, easy to produce, fast, inexpensive	Difficult market availability (fuchsin capsules are not sold)	ND, upper and lower CD	Sieving, colorimeter or spectrophotometer

CD: complete denture; **ND:** Natural dentition; **OD:** overdenture; **RPD:** removable partial denture

Table 3 – Overall information on the methods of assessing masticatory function using a given test food

FORM OF EVALUATION	ADVANTAGE OF THE FORM OF EVALUATION	DISADVANTAGE OF THE FORM OF EVALUATION	FOODS THAT HAVE ALREADY BEEN USED	HOW IT WORKS	COMMENTS/NOTES
Single sieve method	Less work than the multiple sieve method (only one mass measurement), good clinical applicability	Time consuming, little detailing, difficult inter-individual comparison, depends on specific device (sieves and balance)	Optocal	Sieving of the chewed and dried particles, followed by weighing of the sieved particles	The sieve diameter that was chosen must be as close as possible to the average particle size
Multiple sieve method	"Gold standard", reliable, it is possible to determine the average size of the particles, provides detailed information, possibility of comparing inter-individuals and intra-individuals	Time consuming, too many steps, depends on the specific device (sieves and balance)	Optocal, Optosil, CutterSil Silicone, Optozeta, gelatin based cylinder, carrot, almonds, steak	Sieves of different diameters of the chewed and dried particles to assess the weight and distribution of the particles in the sieves	
Viewgum	Good clinical applicability, fast (about 30s according to Halazonetis[52]), easy, efficient, inexpensive (software is free), possibility of comparing inter-individuals and intra-individuals	Need to repeat software analysis	Chewing-gum (Hubba-Bubba), tape of two flavors and colors (blue and pink) that were united (LotteTM, Tokyo; Vividen Fruitswing ''Karpuz/Asai Uzumu '' (Perfetti van Melle, Turkey)	The software evaluates the "HSI" parameters (hue, saturation, intensity) of the image, focusing mainly on the "hue" factor. The higher the variation of the hue axis, the greater the presence of two different colors (badly chewed and mixed gum)	
Photoshop digital analysis, CS3 extended (Adobe, San Jose, CA, USA)	No specific advantages described	No specific disadvantages described	Bicolored wax tablet	The software analyzes the RGB ("red, green, blue") image of the chewed wax and assess the pixels in the intensity of the red and blue colors (which are the colors of the wax)	This article has not focused much on the aspects of the evaluation method (usually the articles that focus more on it are the articles of method validation), but in my opinion the Photoshop has the same advantages as the Viewgum method.

ADOBE PHOTOSHOP digital analysis CS2, version 9.0§),	No specific advantages described	No specific disadvantages described	Trident® chewing-gum of two flavors and colors (red and white) that were united	The software analyzes the image of the chewed gum at a peak of intensity in red and another in white (colors of the gum). As the gum is mixed, the peaks merge and, the lower the standard deviation of the peaks, the better the chewing	This article has not focused much on the aspects of the evaluation method (usually the articles that focus more on it are the articles of method validation), but in my opinion the Photoshop has the same advantages as the Viewgum method
MATLAB digital analysis (MPAT V10, Perceptodent Project, University of Malaga, Spain	No specific advantages described	No specific disadvantages described	Trident® chewing-gum of two flavors and colors (red and white) that were united	The software analyzes the image by the intensity of the colors using the "HSI" parameter and the number of pixels of the colors in the RGB parameter	In the results, the author Vaccaro[59] concludes that evaluating the variation of the hue proved to be the ideal evaluation of this type of testing food.
Image J digital analysis (1.42q; Wayne Rasband, National Institutes of Health, MD, USA.)	Can be used in a standardized food; results like sieving ("gold standard"); according to Eberhard[12], the method can be employed in dentate and prosthetic patients; faster than sieving, more inexpensive than the sieves	It has questionable clinical use because it needs the sieving method to provide the sample reference	Optosil	The chewed Optosil is flattened and scanned. The software uses some parameters to generate values that are exported to excel and from the size reference, the estimated weight is obtained	
Adobe Photoshop Elements 2.0 digital analysis	Easy to learn, well-suited for research, reliable, accurate, easy to standardize	Schimmel[21] reports that even though it is easy to learn, it is not clinically viable	Chewing-gum (azure and White colour, 30 · 18 · 3 mm, Hubba-Bubba Tape Gums*)	The chewed gum is scanned before and after being flattened. The software analyzes the number of blue pixels and a formula was applied to determine the mixing ability from the comparison with non-chewed gums.	

Visual analysis (color chart)	Inexpensive, simple, test can be performed by the patient himself/herself (according to Kamiyama[18]), can be performed on a large scale, reliable and viable in clinical analysis	Difficult access to the chewing-gum, may stick to the prosthesis, not recommended for individuals with alterations in the salivary flow, need for calibration between the observers, inter-examiner discrepancy	Chewing-gum (XYLITOL, Lotte Co., Ltd., Tokyo, Japan)	The gum changes color during chewing due to its sensitivity to pH changes. After chewing the gum was flattened and compared with a visual scale that provides the reference of 5 colors and their performance levels	In Tarkowska's article[66], he mentions that a solution to the gum adhesion would be to include resinous additives, but this may increase its hardness.
Visual analysis (from the score)	Good clinical applicability, fast, efficient, simple	Despite the good correlation, the digital analysis is more accurate	Chewing-gum LotteTM, Tokyo; Vivident Fruitswing ''Karpuz/Asai Uzumu '' (Perfetti van Melle, Turkey). Gum developed from SOR-BITS® (A/S Alfred Benzon, Copenhagen)	Chewed gum is analyzed visually by observers. It can be evaluated before and / or after being flattened	Liedberg[17] used a method of visual analysis with score; however, unlike other articles, his scale was visual. According to Schimmel[21], it is better to evaluate the flattened gum.
Colorimeter (CR-13; Konica-Minolta, Japan).	Reliable, fast, simple	Presence of "random errors" according to Hama 2014	Chewing-gum (XYLITOL, Lotte Co., Ltd., Tokyo, Japan)	Result given by the average obtained by means of the colorimeter in five points of the flattened gum. The colorimeter evaluates the parameters in the CIELAB system in which "L" represents lightness of the color, "A" represents degree between red and green and "B" represents degree between yellow and blue	Some authors like Kamiyama[18] use only parameter A, where the higher its value, the higher the red level and the better the color change.
Spectrophotometer (Beckman Inc., Palo Alto, CA, USA)	Reliable, fast, effective, good sensitivity	Your test food is no longer available	Fuchsin capsules	After the capsule is chewed, its contents are dissolved in distilled water and strained through a filter. The peak of Fuchsin is identified by the device at a wavelength of 546 nm, and the higher the reading (μg / mL), the better the masticatory efficiency	

Sugar Extraction (by mass)	Involves numerous mastication processes (according to Anastassiadou[34]), no loose particles, can be performed at home or home institutions for the elderly, easy	Affected by saliva, high early mass loss, compromised method in individuals with altered salivary flow	Freedent (The Wrigley Company Ltd, Plymouth, Devon PL6 7PR, UK), Dentine-Ice (Warner Lambert, Belgium), Elma-f (Chios Gum Mastic Growers Association, Chios, Greece), Pita (Chios Gum)	The gum is weighed in three moments: before the test, after the test with and without saliva (after drying). A formula involving these weights was used to determine the level of weight loss of the gums, the greater the weight loss of the gum, the better the masticatory efficiency	The author Anastassiadou[34] discusses that the xylitol sweetened gums have high xylitol solubility (losing a lot of mass in the first five chews) in relation to the xylitol dissolved gums.
Sugar Extraction (by sensor)	Low cost, easy, fast	No specific disadvantages described	Gummy Jelly (GC, Tokyo, Japan; LOTTE Co., Ltd., Tokyo, Japan)	After chewing, the individual puts distilled water in the mouth and expels it through a paper filter. The glucose sensor measures the level of glucose present in the filter, and the greater the extraction of glucose, the better the masticatory efficiency	The author Yamamoto[23] indicates using smaller, soft jelly beans for patients with TP, but there are no considerations about the method itself.

CAPÍTULOS

3.3. CAPÍTULO 3

Artigo submetido na Journal of Clinical and Experimental Dentistry 06 / 06 /2022 (JCED Qualis A3 em Odontologia) em 05 / 06 / 2022 – Em fase de adequação/correção para aceite final

MANDIBULAR IMPLANT-ASSISTED REMOVABLE PARTIAL DENTURE - KENNEDY CLASS I TO CLASS III MODIFICATION – CASE SERIES WITH MASTICATORY PERFORMANCE AND SATISFACTION EVALUATION

Rafael Z. Araujo DDS, MS,[a] Karla Zancopé DDS, MS, PhD,[b] Rodrigo S. Moreira DDS,[c] Talita O. Barreto DDS,[d] Flávio D. das Neves DDS, MS, PhD[e]

[a] Doctorate Student of Oral Implantology. School of Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil.

[b] Department of Occlusion, Prosthesis and Dental Material, School of Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil.

[c] Master Degree student of Oral Implantology. School of Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil.

[d] Postgraduate student, Department of Oral Implantology, Núcleo de Ensino e Estética em Odontologia, Itabuna, Bahia, Brazil.

[e] Department of Occlusion, Prosthesis and Dental Material, School of Dentistry, Federal University of Uberlandia, Minas Gerais, Brazil.

Corresponding Author:
Dr. Rafael Zetehaku Araujo
Department of Oclusion, Prosthesis and Dental Material. Federal University of Uberlândia
Av. Pará, 1720 - Umuarama, Uberlândia, Minas Gerais, Brazil.
Box: 38.405-320
Phone number: +55 73 99922-5570
Email: rafaelzaraujo@hotmail.com

ABSTRACT

In this work, we present 5 cases of Kennedy Class I patients with atrophic posterior mandible treated with the placement of 01 short WS Neodent® implant bilaterally and a healing screw to support the removable prosthesis, transforming them into Kennedy Class III patients. To quickly evaluate and verify the benefit of this treatment, masticatory performance was evaluated with maximum bite force and chewing ability. A OHIP-19 questionnaire was also applied for a practical preoperative and postoperative evaluation of overall quality of life-changing for the patient after this treatment. This treatment was planned in order to reduce drastically the treatment costs and morbidity, and to enhance oral function and the quality of life for these patients. Also, this treatment leads to residual bone preservation, enhanced masticatory function and patient satisfaction. Especially in countries with a large number of patients with missing teeth and socio-economic difficulties to be fully rehabilitated with dental implants and fixed prosthesis treatment options with reduced costs are important to be in our armamentary os possibilities.

KEYWORDS: Dental implants, masticatory performance, chewing, oral function, mixing ability

INTRODUCTION

It is still very common, especially in countries with pronounced social inequality, to have a high prevalence of people with tooth loss [1,2]. In this scenario, the need for prosthetic oral rehabilitation with fixed or removable prosthesis is enhanced [1,2]. Some studies show that the percentual of elderly will continue to increase until 2040, and as consequence and surrounded by social, cultural, and economic factors, a larger number of total or partially edentulous patients will also be raised [1,2].

Tooth loss, especially the posterior teeth, may cause a disturbance in the stomatognathic system, affecting sensorial and motor aspects that may interfere with the masticatory process [3-7]. Partially edentulous patients may change their nutrition patterns by chewing limitations, which can lead to

negative health and nutritional issues, and affect their quality of life [3,5]. When the posterior teeth are lost, it is common for the patients to seek softer foods, usually composed of an excess of carbohydrates and lowered in fruits, vegetables, proteins, and nuts, which consequently makes a less nutritive diet [6,8,9]. To overcome the absence of the posterior teeth and recompose the aesthetic and masticatory function, a removable partial prosthesis (RPP), fixed partial prosthesis, or implant retained prosthesis are recommended [6,7,10,11].

The masticatory function may be evaluated through maximum bite force, masticatory performance, or chewing/mixing ability. These methods, which are used to evaluate the masticatory function, have gained great popularity in the latest years, evaluating and comparing treatments and their impact on the quality of life, chewing, and trying to project nutritional aspects for the patients [4,6,11].

Mandibular posterior bone atrophy may lead patients to a series of limitations of treatment options due to the consequences of low bone quality, and often insufficient height and width of residual bone, superficialization of the inferior alveolar nerve, and altered or increased occlusal dimension [7]. For those reasons, when an implant oral rehabilitation is proposed, it is often necessary to initiate with previous reconstructive surgeries. In these cases, we come across some sensitive techniques subjected to a series of complications. Onlay and inlay autogenous bone grafts, guided bone regeneration, split crest technique, alveolar bone distraction, and inferior alveolar nerve lateralization are some of the most cited options in the literature, each of them with their own disadvantages and complications associated [7,8,12]. All these procedures have in common the need for an experience of the surgeon, as well as an increased cost, time of treatment, and morbidity for the patient [12]. An excellent treatment alternative for the atrophic posterior region is the use of short implants [7].

An RPD is a treatment associated with a reduced total cost that may replace several teeth and have a general increase in the patient chewing function [4]. Nevertheless, patients with RPD have a decrease in their masticatory function when compared to fixed treatment options [8,9,10]. In Kennedy

Class I patients treated with RPD, due to the absence of support in posterior teeth, this treatment is reported to presented low retention and stability making chewing difficult and producing pain in the mucosa that is compressed when chewing is taking place [8,14]. This treatment is associated with overall dissatisfaction and oral discomfort by the patient in approximately 60% of the cases, and many abandon the use of this prosthesis [8,14]. Almost 40% of the partially mandibular edentulous patients are classified as Kennedy Class I [15]. Other issues such as increased carious lesions and periodontal disease in the pillar tooth are frequently observed [14,15].

In this work, we present 5 cases of Kennedy Class I patients with atrophic posterior mandible treated with the placement of 01 short WS Neodent® implant bilaterally and a healing screw to support the removable prosthesis, transforming them into Kennedy Class III patients. To quickly evaluate and verify the benefit of this treatment, masticatory performance was evaluated with maximum bite force and chewing ability. A VAS questionnaire was also applied for a practical preoperative and postoperative evaluation of overall quality of oral health-related quality of life-changing for the patient after this treatment. This treatment plan was planned in order to reduce drastically the treatment costs and morbidity, and to enhance oral function and the quality of life for these patients.

CASE SERIES

All these 5 cases reported followed exactly the same protocol. All surgeries were performed by the same surgeon (RZA). All patients were complete maxillary edentulous and mandibular Kennedy Class I (Figure 1). If the total removable superior prosthesis and partial inferior prosthesis were not suitable, a new pair of removable prosthesis were accomplished before implant surgery. A common complaint in all cases was some sort of dissatisfaction with the use of the inferior RPD, usually related to pain when chewing, prosthesis instability, or general discomfort. All patients had severe bone atrophy with indication of reconstructive surgery in the anterior (next to the pillar teeth) and/or posterior mandibular region if a complete implant

planning surgery was the main treatment option (Figure 2).

The impossibility to bear the costs of a complete implant treatment associated or not with reconstructive surgery was a common issue for all of these cases, making this treatment option unavailable. Alternatively, aiming for a significant overall reduction of treatment costs with a treatment that would allow patients to use their RPD with increased comfort, stability, and less mucosal compression and pain during chewing, it was proposed to place short implants bilaterally in the posterior region. The option to use healing screws and not to perform prosthesis implant crown goes in the same direction for cost reduction, whereas the patient would have an additional cost for the crown and for the RPD adaptation or replacement for a new one.

All surgeries followed the same protocol, and were accomplished in the same dental office (Dental School of the Federal University of Uberlandia). After Lidocaine 1:100.000 local anesthetics were accomplished, a small crestal incision and periosteal elevation was made only on the region of implant placement. If the last remaining teeth were the 1º or 2º Pre-molar, implants would be placed in the 2º molar region. If the last remaining pillar teed were the canines or anterior, the implants would be installed in the 1º molar region. All implants were Neodent® WS short implants, with 4mm width and 5 or 6mm height. All surgeries were executed with the assistance of parallelizer pins to help to guide the 3-dimensional implant angulation and the occlusal patient reference (Figure 3).

All patients were submitted to a 2-time protocol, and a period of 4 months was waited for the osseointegration period before reopening the implants (Figure 4). After 1 to 2 weeks after healing screws were installed, sutures were removed and the patient initiated the use of their RPD over the implant/healing screw. Follow-up revisions were each 15 days in the first 2 months and then monthly until the sixth month. After that, patients were placed on a regular follow-up schedule, with 2 visits per year or before that if any issue would arise. During the follow-up appointments, if necessary, adjustments were made in the RPD and a substitution in the healing screw was accomplished so it could remain at a 0.5mm or maximum 1mm above the gingival tissue (Figure

5).

Before implant surgery and 6 months after healing screw placement, all patients were evaluated for a satisfaction survey with a VAS (Visual analogue scale) questionnaire and for the masticatory function with a maximum bite force and mixing ability test. All these tests and questionnaires are easy to perform, quick, validated by the literature, and reliable to evaluate treatment outcomes. The maximum bite force was evaluated with the use of a Gnatodynamometer. The patient bites 5 times on the right side and the highest and lowest result was discarded. The other 3 were made an average to obtain the final result (Figure 6). Masticatory performance was evaluated through chewing gum and specific software developed to analyze the mixed gum (Figure 7). This methodology is widely used for masticatory performance evaluation purposes in the literature. All the results of the VAS were positive for all patients. Maximum bite force increased in all cases and masticatory performance was also enhanced for all 5 patients (Table 1). With 1 year of follow-up, no patient has had any major complaints or implant loss. Only 2 cases of healing screw loosening happened and were solved with regular appointment and clenching. In follow-up appointments healing screws were detached, polished, and torqued again, and if RPD adjustments were necessary, they were accomplished.

DISCUSSION

Kennedy Class I patients, but mostly in any other patient with several tooth losses, problems with chewing impairment, muscular disturbance, and decreased nutrition and quality of life may be a negative consequence [5,8,17]. The RPD for Kennedy Class I patients may lead to poor retention, stability, and ultimately abandonment of the prosthesis use. Nowadays, the importance of increasing or maintaining masticatory capacity is a favorable factor in healthy aging and preservation of some cognitive functions [18,19].

Placement of short implants to support bilateral free end mandibular prosthesis is being published by some papers in the last few years in the literature. This treatment has some advantages for the

patient such as low treatment cost, preservation of the residual bone, reduced morbidity treatment option, better loading distribution in the pillar removable prosthesis teeth (and increased tooth survival), increased speech ability and masticatory function, better prosthesis stability and comfort during chewing, and ultimately, enhanced satisfaction and patient quality of life [9,12,13,20-24].

It has already been suggested that 3 masticatory units are sufficient to create a significative positive outcome in the masticatory performance of patients (shortened dental arch). In our cases reported, the maximum bite and mixing ability prove these improvements [22,24]. Placement of implant, if in the 1º or 2º molar region, will depend on the remaining pillar teeth [22]. The position of the short implant must be carefully planned to aim the support the RPD and even make it possible (if so desired), to the placement of additional implants for a fixed partial prosthesis. Systematic reviews demonstrated good survival rates for this type of treatment, varying between 91.7 - 100%, similar to other mandibular regions used exclusively to support implant fixed prosthesis [22-24].

We did not find any major complications in our case series. During the follow-up period it was necessary to replace some of the healing screws to adjust their height to be 0.5mm to a maximum of 01mm above the gingival soft tissue. Only 2 patients showed loosening of one of the healing screws before the scheduled appointment. Any other major complication in regard to peri-implant tissue or bone loss was not observed. Patients are followed with periapical radiographs. Other literature reviews of this type of treatment also do not report major complications as an issue to be concerned [22,23,24].

To evaluate the effectiveness of this technique we used a satisfaction questionnaire (SATS-PRO), which provides an estimative of the impact of the buccal conditions in edentulous patients [25]. All patients had better results regarding their personal satisfaction after the treatment indicating enhancement of the quality of life, both physical and psychological. Another aspect evaluated was the masticatory performance to verify if the use of these short implants/healing screw would

provide good support for the RPD with functional results. The use of a bicolor chewing gum provides a test of mixing ability and is capable to be analyzed by a specific developed software Viewgum®, which allows to establish through graphics and numerical results the masticatory efficiency through the mixing of the colors of the gum [26,27]. The maximum bite force provides us objective numerical data on the chewing capacity of the patient, and if it is increased we expect that the patient may include in his/her diet harder and more consistent food, such as meat, nuts, fruits, and vegetables. Both masticatory performance tests showed improved results, as we can see in Table 1. Sats-Pro questionnaire also pointed to improvement in the satisfaction of the patient with the treatment after implant placement. All of these tests are easy to perform, fast, with low cost, and may be incorporated and applied in our daily routine in our offices. They are important tools to create treatment data, communicate to the patient, and also for legal purposes.

CONCLUSION

Placement of short implants to support RPD in Kennedy Class I mandibular patients has several advantages such as low cost, residual bone preservation, low morbidity, better masticatory loading distribution, and enhanced masticatory function and patient satisfaction [10,13,14,21,22]. Especially in countries with a large number of patients with missing teeth and socio-economic difficulties to be fully rehabilitated with dental implants and fixed prosthesis treatment options with reduced costs are important to be in our armamentary os possibilities. Also, patiens may not be able or do no want to perform complex reconstructive surgeries previous to dental implant placement. Although it has a series of limitations, this treatment may pose as a good alternative for patients with the profile describe in this manuscript. It is important to highlight that many of those patients are elderly, and a treatment that reduces morbidity and overall treatment time is always convenient.

REFERENCES

1. Cardoso M, Balducci I, Telles D de M, Lourenço EJV, Nogueira Júnior L. Edentulismo no Brasil: Tendências, projeções e expectativas até 2040. Cien Saude Colet 2016;21:1239-46.

2. Aguiar VR, Celeste RK. The need for, and allocation of, regional prosthodontics laboratories in Brazil: An exploratory study. Cien Saude Colet 2015;20:3121-8

3. Tada A, Miura H. Association between mastication and cognitive status: A systematic review. Arch Gerontol Geriatr 2017;70:44-53.

4. Vega TMS, Schimmel M, Van der Bilt A, Chen J, Van der Glas HW, Kohyama H, Hennequin M, Peyron MA, Woda A, Leles CR, Pereira LJ. Consensus on the terminologies and methodologies for masticatory assessment. J Oral Rehabil 2021;48:745-61.

5. Goncalves TMSV, Campos CH, Garcia RCMR. Effects of Implant-Based Prostheses on Mastication, Nutritional Intake, and Oral Health–Related Quality of Life in Partially Edentulous Patients: A Paired Clinical Trial. Int J Oral Maxillofac Implants 2015;30:391–6.

6. Neves FD, Mendes FA, Borges TF, Mendonça DBS, Prado MMS, Zancopé K. Masticatory performance with different types of rehabilitation of the edentulous mandible. Braz J Oral Sci 2015;14:186-9.

7. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Implant retention and support for distal extension partial removable dental prostheses: Satisfaction outcomes. J Prosthet Dent 2014;112:334–9.

8. Campos CH, Gonçalves TMSV, Rodrigues Garcia RCM. Implant retainers for free-end removable partial dentures affect mastication and nutrient intake. Clin Oral Implants Res 2014;25:957–61.

9. Wismeijer D, Tawse-Smith A, Payne AGT. Multicentre prospective evaluation of implant-assisted mandibular bilateral distal extension removable partial dentures: Patient satisfaction. Clin Oral Implants Res 2013;24:20–7.

10. Gonçalves TM, Campos CH, Gonçalves GM, de Moraes M, Rodrigues Garcia RC.

Mastication improvement after partial implant-supported prosthesis use. J Dent Res 2013;92:189S-94S.

11. Bidra AS, Almas K. Mini implants for definitive prosthodontic treatment: A systematic review. J Prosthet Dent 2013;109:156–64.

12. Pistilli R., Felice P., Cannizzaro G., Piatelli M., Corvino V., Barausse C., Buti J., Soardi E., Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long 4 mm wide implants or by longer implants in augmented bone. One-year post-loading results from a pilot randomised controlled trial. Eur J Oral Implant 2013;6:359–372.

13. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Mastication and jaw motion of partially edentulous patients are affected by different implant-based prostheses. J Oral Rehabil 2014;4:507–14.

14. Shahmiri RA, Atieh MA. Mandibular Kennedy Class I implant-tooth-borne removable partial denture: A systematic review. J Oral Rehabil 2010; 37(3):225-34.

15. Curtis DA, Curtis TA, Wagnild GW, Finzen FC. Incidence of various classes of removable partial dentures. J Prosthet Dent 1992;67:664-7.

16. Kordatzis K, Wright PS, Meijer HJ. Posterior mandibular residual ridge resorption in patients with conventional dentures and implant overdentures. Int J Oral Maxillofac Implants 2003;18:447-52.

17. Oliveira NM, Shaddox LM, Toda C, Paleari AG, Pero AC, Compagnoni MA. Methods for evaluation of masticatory efficiency in conventional complete denture wearers: a systematized review. Oral Health Dent Manag 2014;13:757-62.

18. Lee IC, Yang YH, Ho PS, Lee IC. Chewing ability, nutritional status and quality of life. J Oral Rehabil 2014;41:79-86.

19. Okamoto N, Morikawa M, Okamoto K, Habu N, Hazaki K, Harano A, et al. Tooth loss is associated with mild memory impairment in the elderly: the Fujiwara-kyo study. Brain Research 2010;1349:68-75.

20. Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. Implant retention and support for distal extension partial removable dental prostheses: Satisfaction outcomes. J Prosthet Dent 2014;112:334–9.

21. Zancopé K, Abrão GM, Karam FK, Neves FD. Placement of a distal implant to convert a mandibular removable Kennedy class I to an implant-supported partial removable Class III dental prosthesis: A systematic review. J Prosthet Dent 2015;113:528-533.

22. Park JH, Lee J-Y, Shin S-W, Kim S-J. Effect of conversion to implant-assisted removable partial denture in patients with mandibular Kennedy classification: A systematic review and meta-analysis. Clin Oral Impl Res 2020;31:360–373.

23. Bassetti RG, Bassetti MA, Kuttenberger J. Implant-Assisted Removable Partial Denture Prostheses: A Critical Review of Selected Literature Int J Prosthodont 2018;31:287-302.

24. Gutierres Filho PJB, Fernandes JMGA, Ferreira LD, Lima DB, Silva R. Tradução e adaptação transcultural do Questionnaire de Satisfaction de la Personne Amputée face à as Prothèse (SAT-PRO) para a língua portuguesa do Brasil. Acta Fisiatr 2020;27:20

25. Souza RF, Patrocínio L, Pero AC, Marra J, Compagnoni MA. Reliability and validation of a Brazilian version of the Oral Health Impact Profile for assessing edentulous subjects. J Oral Rehabil 2007;34:821–6.

26. Halazonetis DJ, Schimmel M, Antonarakis GS, Christou P. Novel software for quantitative evaluation and graphical representation of masticatory efficiency. J Oral Rehabil 2013;40:329–35.

27. Silva LC, Nogueira TE, Rios LF, Schimmel M, Leles CR. Reliability of a two-colour chewing gum test to assess masticatory performance in complete denture wearers. J Oral Rehabil 2018;45:301–7.

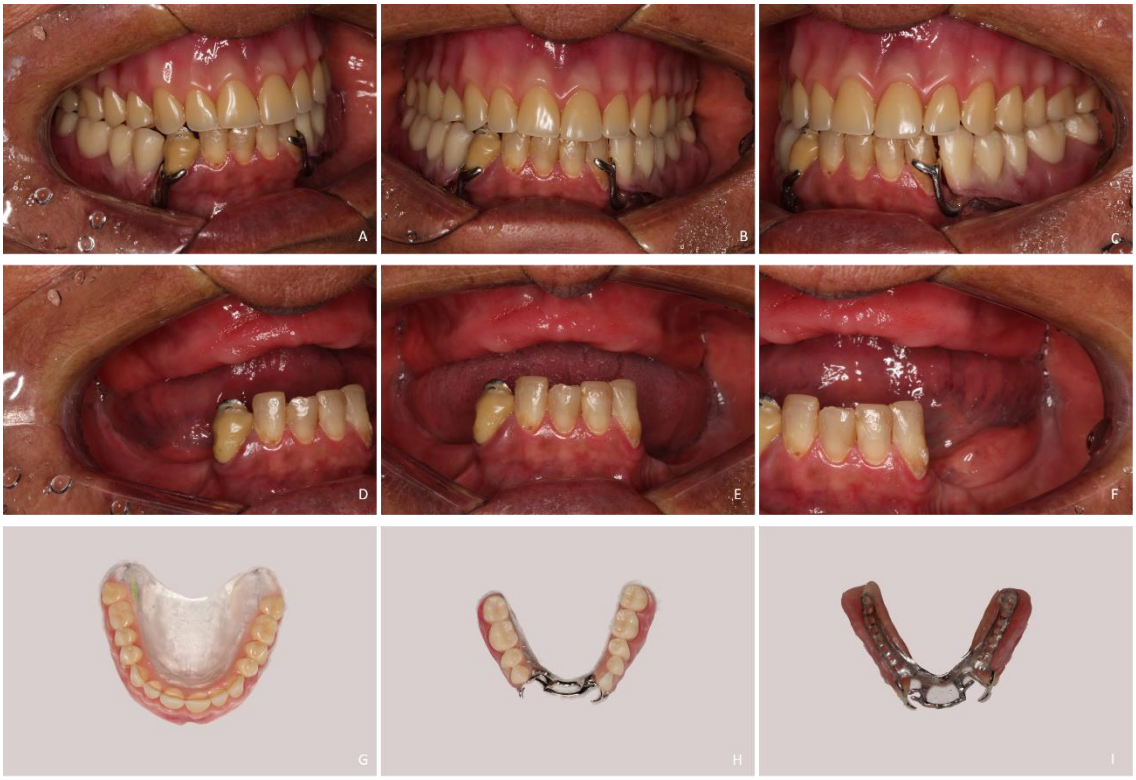


Figure 1 – Preoperative intraoral photographs. A, B, C. Preoperative intraoral photographs using upper complete denture and lower partial denture. D, E, F. Frontal and lateral intraoral photograph without the removable dentures showing residual ridge depth and bone atrophy. G, H, I. Photographs of the upper complete denture and lower partial denture used by the patient before implant placement

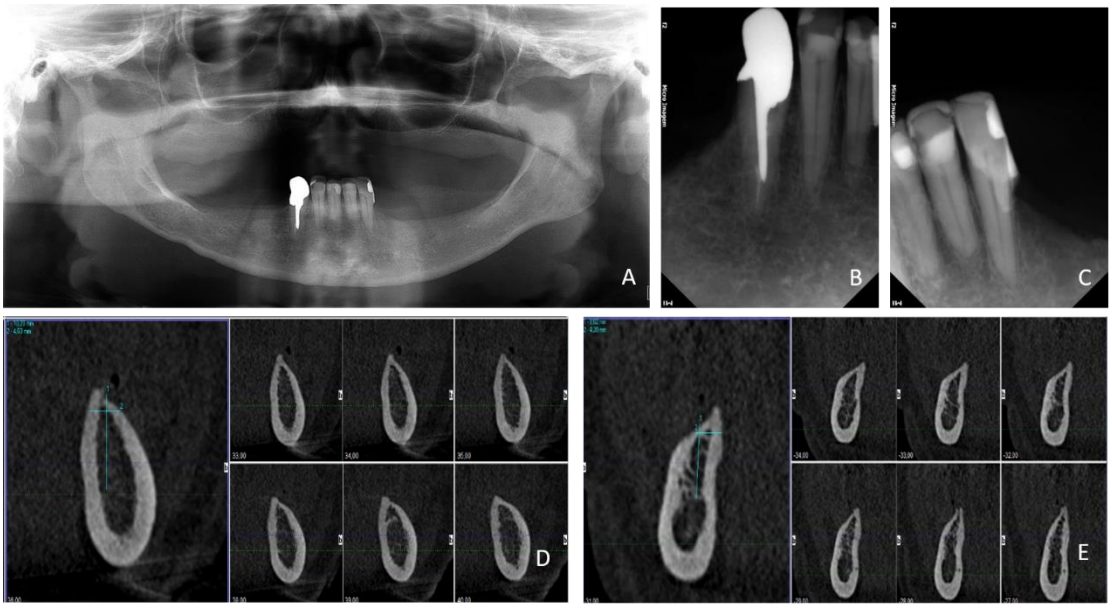


Figure 2 – Preoperative radiographic and tomographic images. A. Preoperative panoramic radiography. B and C, Periapical radiographs of the pillar teeth for the removable prosthesis, the right canine, and left lateral incisor. D, E. Computed tomography of the regions planned for implant placement. It is possible to see the bone atrophy on the mandibular posterior region on both sides.

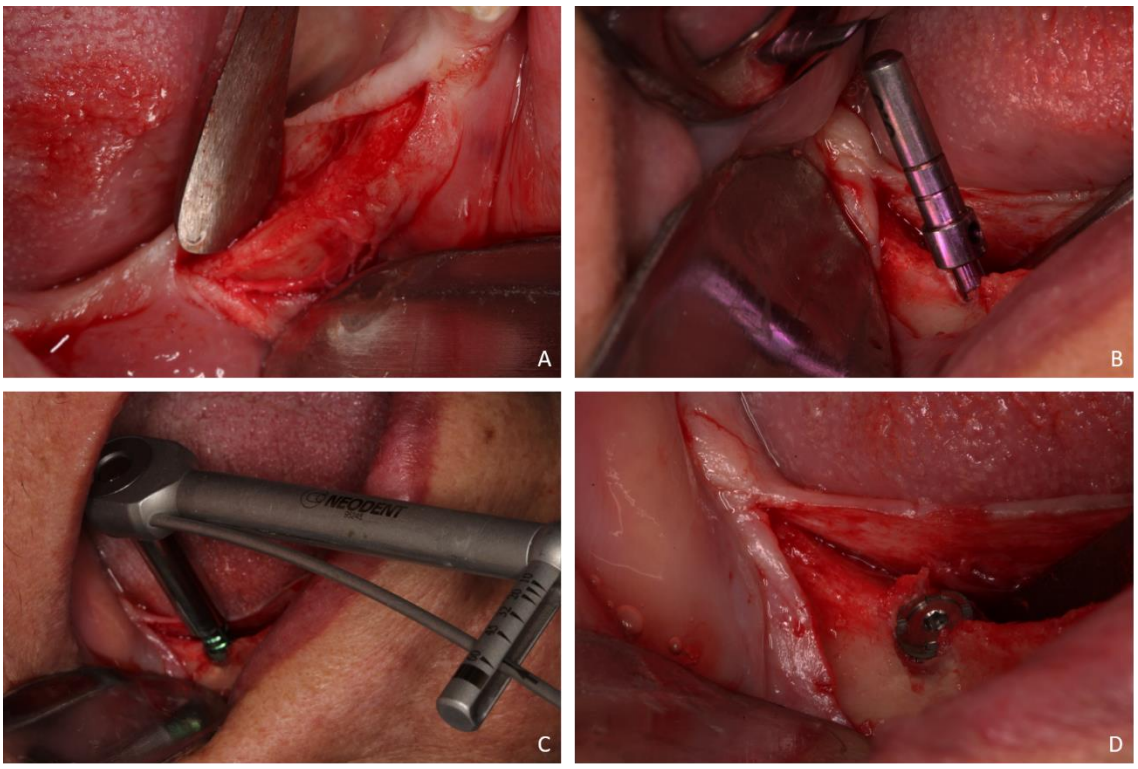


Figure 3 – Implant surgery placement. All surgeries followed the same protocol. A. Alveolar ridge incision and periosteal tissue detachment. B. After the 2.0 drilling, a parallelizer was placed to check the correct tridimensional position of the implant to be inserted. C. Implant engaged and torque measuring. D. Implant installed with a cover screw to be reopened in 4 months.

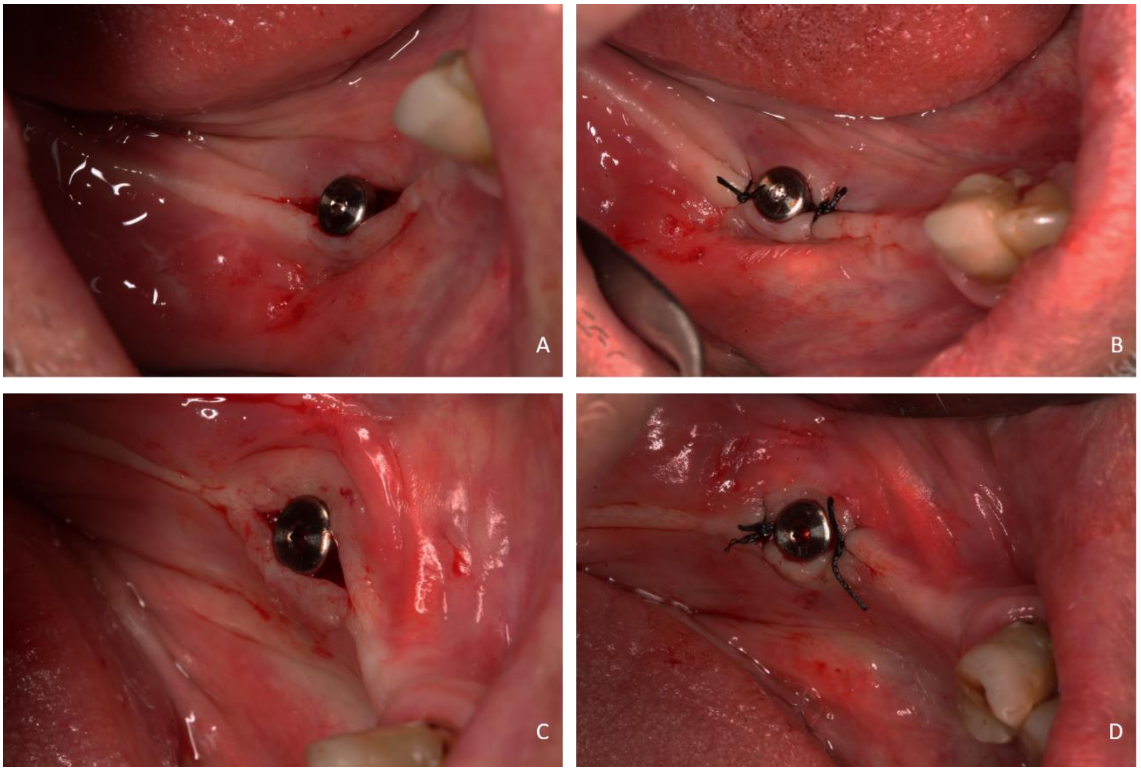


Figure 4 – Reopening surgery after 4 months of osseointegration period. A,C. A small incision is accomplished to expose the implant. B, D. Silk suture was placed on both sides after the cover screw was properly selected and torqued.

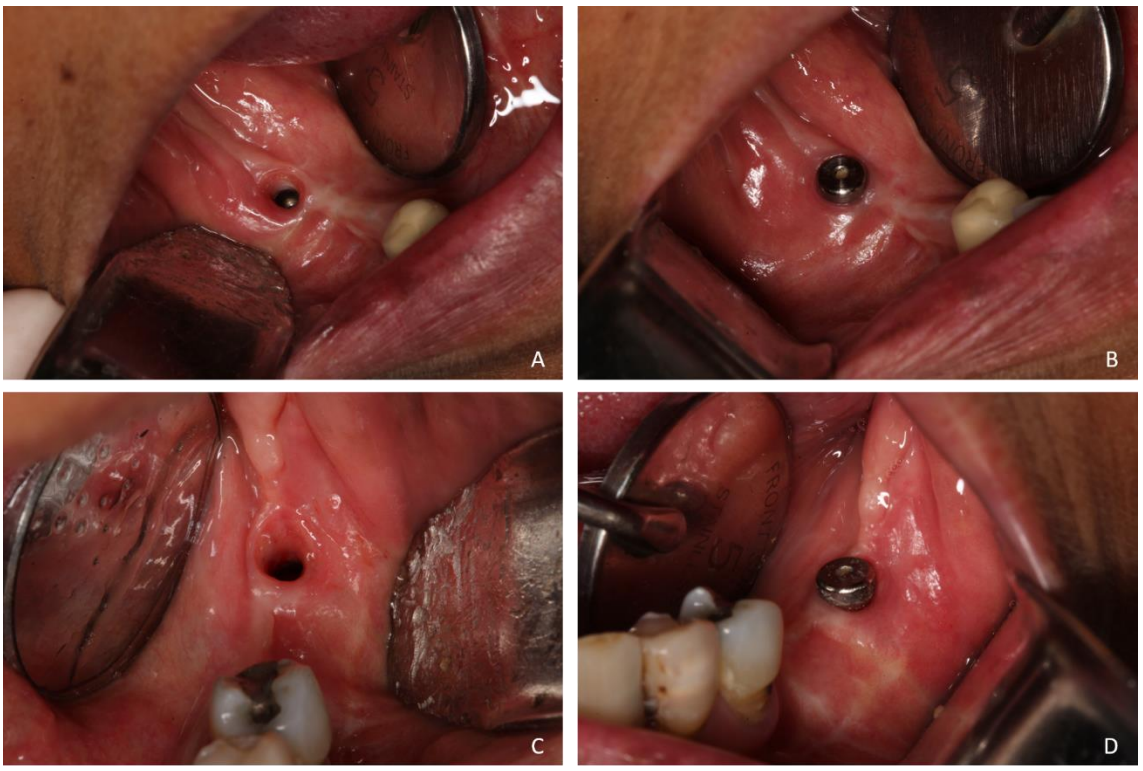


Figure 5 – In the follow-up periods, if the healing screw were more than 1mm above the soft tissues, they were changed to a smaller one. A, C. Soft tissue aspect without the healer bilaterally. B, D. Replacement of the healer on the right side and left side respectively.

Figure 6 – Maximum Bite Force measurement. A and B – Measurement of the maximum bite force with the Gnatodynamometer.

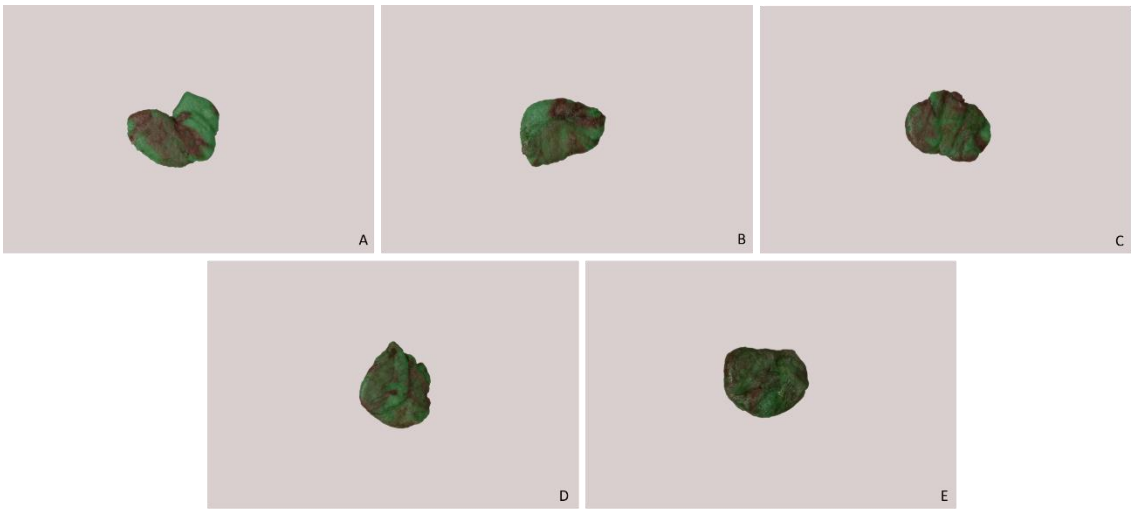


Figure 7 – Photographic image that is submitted to the Viewgum software for assessment of the

mixed chewing gum in the postoperative period. A, Chewed gum after 5 chewing cycles. B, Chewed gum after 10 chewing cycles. C, Chewed gum after 20 chewing cycles. D, Chewed gum after 30 chewing cycles. E, Chewed gum after 40 chewing cycles.

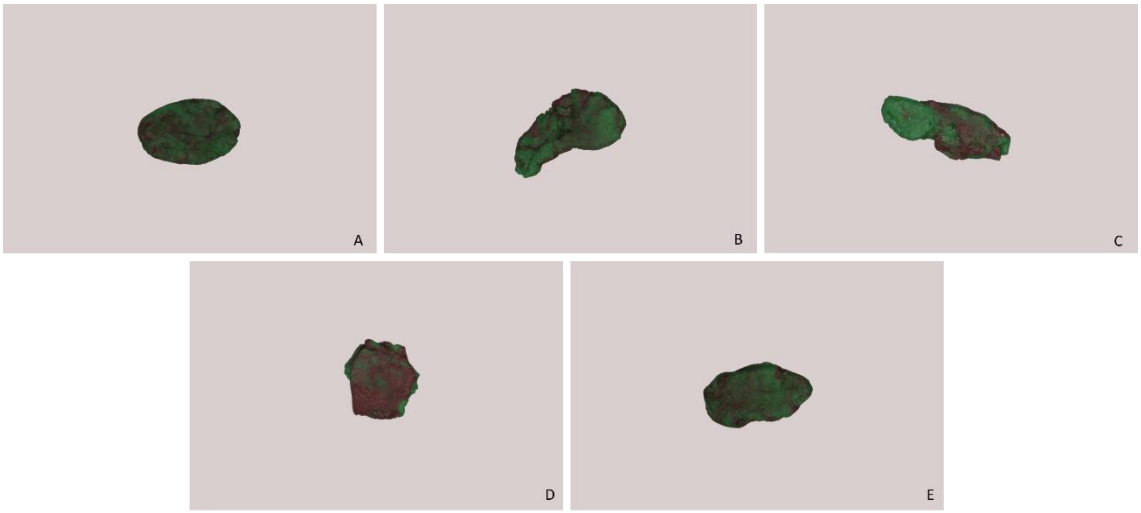


Figure 8 – Photographic image that is submitted to the Viewgum software for assessment of the mixed chewing gum in the postoperative period. A, Chewed gum after 5 chewing cycles. B, Chewed gum after 10 chewing cycles. C, Chewed gum after 20 chewing cycles. D, Chewed gum after 30 chewing cycles. E, Chewed gum after 40 chewing cycles.

Patient Age	**Systemic Disease**	**Neodent WS Implant**	**Maximum bite force (Right side)**		**Viewgum Software**		**Sats-P**	**Complications**
A.M. 91 Years	Controlled Diabetes and Hypertension Cardiac Condition	Right side 4x6 Left side 4x6	Pre- op 9,256	Post-op 13.009	Pre-op 5 cycles	Post-op 5 cycles	Positive difference in regard to prosthesis retention and stability	Change of healing screw with 2 months from 2.5mm to 1.5mm on the left side
					-0,841	-1,166		
					Pre-op 10 cycles	Post-op 10 cycles		
					1,037	-0,045		
					Pre-op 20 cycles	Post-op 20 cycles		
					4,709	3,194		
					Pre-op 30 cycles	Post-op 30 cycles		
					9,022	5,941		
					Pre-op 40 cycles	Post-op 40 cycles		
					15,836	10,704		
C.C.A. 61 Years	Controlled Diabetes and Hypertension	Right side 4x6 Left side 4x5	Pre- op 5,516	Post-op 8,883	Pre-op 5 cycles	Post-op 5 cycles	Positive difference in regard to prosthesis	Change of healing screw with 2 months
					-0,625	-1,575		
					Pre-op 10 cycles	Post-op 10 cycles		
					0,846	-0,241		
					Pre-op 20 cycles	Post-op 20 cycles		

	Asma Cardiac Condition				3,317 Pre-op 30 cycles 7,753 Pre-op 40 cycles 14,048	1,823 Post-op 30 cycles 3,873 Post-op 40 cycles 11,082	retention, stability and comfort	from 3.5mm to 2.5mm on the left side
E.B.M. 67 Years	Controlled Diabetes and Hypertension Hypothyroidism	Right side 4x6 Left side 4x6	Pre- op 2,416	Post-op 7,533	Pre-op 5 cycles 0,020 Pre-op 10 cycles 0,524 Pre-op 20 cycles 3,590 Pre-op 30 cycles 6,471 Pre-op 40 cycles 15,985	Post-op 5 cycles -1,516 Post-op 10 cycles 0,018 Post-op 20 cycles 2,753 Post-op 30 cycles 5,693 Post-op 40 cycles 11,427	Positive difference in regard to prosthesis retention and stability	Pain When chewing. After healing screws Where changed, patient reported no more pain.
M.M.S. 75 Years	Not reported	Right side 4x5 Left side 4x5	Pre- op 9,166	Post-op 11,983	Pre-op 5 cycles -0,296 Pre-op 10 cycles 2,336 Pre-op 20 cycles 6,756 Pre-op 30 cycles 11,835 Pre-op 40 cycles 20,053	Post-op 5 cycles -0,534 Post-op 10 cycles 0,390 Post-op 20 cycles 4,068 Post-op 30 cycles 7,223 Post-op 40 cycles 13,422	Only a slight difference in regard to better stability	Not reported
S.M.S. 57 Years	Not reported	Right side 4x6 Left side 4x6	Pre- op 4,816	Post-op 6,558	Pre-op 5 cycles -0,956 Pre-op 10 cycles 0,607 Pre-op 20 cycles 3,701 Pre-op 30 cycles 7,809 Pre-op 40 cycles 13,810	Post-op 5 cycles -1,431 Post-op 10 cycles 0,307 Post-op 20 cycles 4,117 Post-op 30 cycles 6,138 Post-op 40 cycles 11,431	Positive difference in regard to prosthesis retention, stability and comfort	Healing screw loosening with 4 months.

Table 1. Data from the 5 consecutive patients

CAPÍTULOS

3.4. CAPÍTULO 4

Artigo submetido na Journal of Oral Implantology em 06 / 04 / 2022 (JOI Qualis B1 em Odontologia) – Em fase de adequação/correção para aceite final

SHORT DENTAL IMPLANTS IN POSTERIOR SINGLE CROWNS: A FIVE-YEAR FOLLOW-UP OF A DESCRIPTIVE TRIAL STUDY

Clebio D. Silveira Junior DDS, MS, PhD, [a] Rafael Z. Araujo DDS, MS, [b] Helder H. M. de Menezes DDS, MS, PhD ,[d] Flávio D. das Neves DDS, MS, PhD [e]

[a] Technical Health School. Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

[b] Doctorate Student of Oral Implantology. School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

[c] Private practice. HD Dental Learning School, Uberlandia, Minas Gerais, Brazil.

[d] Professor, Department of Occlusion, Prosthesis and Dental Material, School of Dentistry, Federal University of Uberlandia (UFU), Uberlandia, Minas Gerais, Brazil.

Corresponding Author:
Prof. Flávio Domingues das Neves
Department of Oclusion, Prosthesis and Dental Material. Federal University of Uberlândia
Av. Pará, 1720 - Umuarama, Uberlândia, Minas Gerais, Brazil.
Box: 38.405-320
Phone number: +55 34 99971-3983
Email: flaviodominguesneves@gmail.com

ABSTRACT

Short implants emerged in order to enable dental rehabilitation for a greater number of patients, especially those with insufficient bone volume, avoiding reconstructive surgeries, reducing treatment time, morbidity

and costs. Considering implant design, surface and prosthetic connection, a formulated hypothesis was generated and tested that Neodent Titamax WS short implants present success rates similar to regular implants even when used for single crowns. Eighteen patients with posterior edentulism and maximum bone height of 7mm and width of 6mm were selected. Peri-implant bone level, crown/implant ratio and the crown's mesiodistal distance were the quantitative variables studied. Vertical and horizontal peri-implant bone loss were measured up to 5 year-follow up in 4 different periods. Of the total 20 implants placed, only 1 was lost due to lack of osseointegration and a success rate over the 5-year follow-up period of 95%. There was no statistically significant association between vertical bone loss and crown / implant ratio (P = 0.530) or mesio-distal width (P = 0.378). The short implants studied in this work showed a success rate and vertical peri-implant bone loss greater than or equal to the indexes found for regular implants in the literature. The different proportions of implant length and crown did not have any effect on bone loss. For short implants, a Morse taper conecction may be favorable. Placement of Neodent WS implants (and similar implants) in an intra-osseous protocol and not at bone level needs further investigation because it might present better results in regard to vertical bone loss over time.

Keywords: short implants; dental implant; bone graft; reconstructive surgery; sinus lift; alveolar ridge.

INTRODUCTION

Short implants emerged in order to enable the oral rehabilitation for a greater number of patients, especially those with insufficient bone height and volume. The posterior region of both the maxilla and mandible, may present some anatomical limitations that may difficult or even prevent the placement of conventional implants without bone graft surgeries or other associated techniques, due to the lack of sufficient bone height. These limitations are associated to the presence of the mandibular canal and mental foramen on the mandible and the maxillary sinus on the maxilla. The literature is still controversial on the definition of short implants. Most authors consider implants shorter than 10 mm in length to be the case, and most recently, some studies suggest short implants to be from 5 to 7mm length and ultra-short implants to be 4-5mm [1-7].

In order to provide height and width in cases of bone atrophy, several reconstructive surgical

techniques are proposed. Some of the proposed reconstructive surgeries involve bone grafts in onlay and inlay techniques, sinus lifting, osteogenic distraction, split crest fracture, guided bone regeneration (GBR) and mandibular canal deviation (also known as inferior alveolar nerve lateralization) [7-12]. Although extensively described in the literature, all these techniques have their own complexity and associated intra or post-operative complications, making difficult to ensure excellent prognosis for them [3,4,7]. In the case of insufficient bone height where reconstructive surgery is aimed to overcome this deficiency, the results are even more discouraging [4-7,9]. In general, these techniques increase the final cost of treatment, prolong the total time for complete oral rehabilitation and represent at least one or more surgical steps increasing morbidity. Also, the risks of complications are increased. In fact, a large number of patients abandon treatment with dental implants when is proposed that they must be prepared with prior reconstructive surgery, and they might quit treatment because they do not have satisfactory systemic conditions or simply because they refuse to undergo reconstructive preparatory surgeries since they are more invasive, time and cost-consuming and with complicated postoperative procedures. According to some authors, this fact justifies the use of short implants whenever possible, thus reducing the time, cost and morbidity of the treatment [1,10-15].

Several studies have shown that some biomechanical characteristics are important for the success of treatments with short implants [16]. Increasing the diameter of these implants seems to be important to increase mechanical stability as it allows for an increase in the bone/implant contact area [4,7]. The implant surface treatment also promotes an increase in the bone/implant contact area and has osteoconductive properties that improve mechanical and biological stability and can reduce the waiting time for osseointegration or even allow for immediate loading [17,18]. Some authors have shown inferior results for short implants compared with conventional implants when they had smooth surfaces [19,20]. However, recent studies from the past decade, have shown improvements in the success rates of short implants when they had surface treatment, comparable to conventional implants [3,10,21].

In treatments with short implants, the crown/implant ratio is apparently unfavorable. This is because vertical bone loss increases the intermaxillary space. Studies have shown that implant treatments can withstand a higher crown/implant ratio than treatments with dentures on teeth [17,22-24]. The type of prosthesis/implant connection is an important factor for the success of short implants [25]. The internal

connections allow for greater stability of the prosthesis and a better distribution of occlusal forces on the implants long axis [26,27]. It is not a coincidence that the worst results for the use of short implants use external hexagonal connections [19,20,28]. Nevertheless, studies using short implants with internal connections yield more favorable results, without differences in the success rates between short and conventional implants [2,10,29].

Systematic reviews showed similar success rates between short and long implants regardless of design, surface and diameter [1,3,4,7,30]. These authors suggest that short implants should be used as an alternative to long implants in cases where additional previous surgeries are necessary [1,3,4,7,30].

The use of short implants for single cases has been the subject of some clinical studies in recent years and favorable results have been achieved[2]. These works have some characteristics in common, such as the use of implants with treated surfaces and internal conical prosthetic connections.

Based on the presented literature and considering the biomechanical characteristics of the surface and the prosthetic connection, a formulated hypothesis was generated and tested that Titamax WS (Neodent / Straumann - Curitiba, Brazil) short implants present success rates similar to those achieved with implants greater than 7mm in length even when used for single crowns.

2 - MATERIALS AND METHODS

2.1 - PATIENT SELECTION

Patient selection began with clinical examination and evaluation of periapical radiographs. When the patient met the desired profile, a tomographic examination of the toothless region was requested to carry out the surgical planning and implant placement. Patients were over 18 years old and had posterior tooth loss, in the molar and/or premolar regions. The following inclusion and exclusion criteria were followed:

2.1.1 - INCLUSION CRITERIA:

- Posterior edentulous areas with bone height between 5 and 7 mm maximum
- Bone width of at least 6 mm to allow for the use of Titamax WS implants with a minimum diameter of 4 mm.
- Natural antagonistic teeth or fixed prosthesis

- Alveolar ridge fully healed (at least 4 months from previous dental extraction)

2.1.2 - EXCLUSION CRITERIA:

- Severe systemic diseases (eg, uncontrolled diabetes and autoimmune diseases);
- Patients undergoing radiotherapy in the past 12 months in the head and neck region;
- Patients undergoing chemotherapy in the last 12 months;
- Presence of local conditions that may compromise the success of the treatment (eg, uncontrolled periodontal disease);
- Non-collaborating patients;
- Patients who use drugs or abuse alcohol;
- Patients who do not sign the informed consent form

This study was approved by the Research Ethics Committee of the Faculty of Dentistry of Ribeirão Preto / USP (no 2009.1.199.58.3) and each patient received a free and informed consent form that included written explanations about the procedures to be performed and the contact numbers of the responsible researcher.

Twenty Titamax WS implants were installed in 18 patients. Nine implants were installed in the mandible and 11 implants in the maxilla. These implants have a cylindrical body, a Morse cone prosthetic interface and a double treated surface with oxide blasting and acid subtraction. For diagnostic and planning purposes, they were divided into two groups, Titamax WS Cortical and Titamax WS Medular. The first ones have cutting characteristics on the threads and apex and therefore are more suitable for bone types 1 and 2. Titamax WS Medular implants have thread and apex characteristics that promote better locking and stability in predominantly medullary bone.

2.2 - SURGICAL PROTOCOL

All implants were installed by the same professional, experienced in the surgical area. After terminal infiltrative anesthesia, an incision and total flap folding were performed. For osteotomy, the drilling sequence protocol indicated in the company catalog and surgical guide was followed. In some situations,

this protocol has been altered to achieve the desired locking and primary stability of the WS implant. In situations where it was found low bone density, sub-instrumentation was performed in order to achieve higher stability torque; in others, where the bone was bone density was high and/or very mineralized, the last drill was repeated to decrease the locking torque. Thus, by changing the surgical technique, a minimum installation torque of 20 N/cm and a maximum of 60Ncm was achieved for all cases.

The drilling speed was 250 RPM (rotation per minute) and the implant setting speed was 25 RPM. In some cases of low-quality bone tissue, manual installation was performed with a surgical torquemeter (Neodent - Curitiba, Brazil. / Cod. 104.027). The final millimeters of the implant placement were achieved with a torquemeter, for measure purposes. After implant placement, selection of the WS Abutment (Neodent - Curitiba, Brazil) was most appropriate for each case using the prosthetic selection components present in the WS Surgical Kit (Neodent - Curitiba, Brazil). The selected WS Abutment was then installed with manual torque so that a periapical radiography could be performed with the radiographic standard guide. This procedure will be better explained in the item “Radiographic evaluations” of peri-implant bone loss. After periapical radiography was taken, the abutment was removed and the cover screw installed (Neodent - Curitiba, Brazil Code 117.016.) for subsequent suturing of the gingival tissue in a 2-step implant placement protocol.

Implants installed in the mandible were reopened after 4 months of waiting for osseointegration and implants installed in the maxilla were reopened after 6 months. Some of the surgical steps and initial planning are illustrated in Figure 1, 2 and 3.

2.3- PROSTHETIC PROTOCOL

On surgical reopening, the abutments previously selected were installed with the torque of 32 Ncm indicated by the manufacturer. A prosthetic torquemeter was used (Neodent - Curitiba, Brazil./ Cod. 104.026). These abutments received the protection cylinders (GT / Neodent Protection Cylinder - Curitiba, Brazil./Cod .: 106.102) during the soft tissue healing, thus enabling the subsequent prosthetic procedures (Figure 4).

Impressions were performed after the peri-implant tissue healing period. In the laboratory, the cast die was made and mounted on a semi-adjustable articulator. The infrastructure was waxed on castable

cylinders (GT / Neodent Cylinder - Curitiba, Brazil./ Code: 118.180), cast in Nickel-Chrome alloys (Fit Cast-SB Plus / Talmax - Curitiba, Brazil) and then received the porcelain layer (Super Porcelain EX 3 / Noritake - Japan) as an aesthetic covering material (Figure 5).

Clinical sessions of infrastructure adjustments followed by porcelain adjustments were carried out. The crowns were definitely installed after the glazed surface under a torque of 10Ncm. Occlusal tables were reduced to contribute with the occlusal force distribution on the long axis of the implants, and lower cusps were also made.

2.4 - DATA COLLECTION

The radiographic measurements of the peri-implant bone level, the crown / implant ratio and the crown's mesiodistal distance were the quantitative variables studied (Table 1).

2.4.1 - RADIOGRAPHIC EVALUATION OF PERI-IMPLANT BONE LOSS:

Periapical radiographic evaluations were performed at different periods to monitor possible changes in the bone level or to check for the presence of radiolucent areas around the implants. The first radiograph was taken at implant surgery placement (T1), the second radiograph was taken at the final prosthesis setting (T2), the third radiographic measure was taken after one year with the final prosthesis in function (T3), the fourth radiograph was performed after 3 years of function (T4) and the fifth and final radiographic measure after 5 years of function (T5).

To determine the amount of bone loss for each period, the measurement of the final bone level was subtracted from the measurement of the bone level at the beginning of the evaluated period. The change in bone level was analyzed in four different periods, from the surgical implant placement to the initial prosthesis setting (period 1), immediately after the prosthesis placement to 1 year of function (Period 2), from the initial prosthesis placed to 3 years of function (Period 3) and from the initial prosthesis placed to 5 years of function (period 4) All the radiographic images from the 4 periods can be illustrated in Figure 6.

Radiographic measures were made using the long cone technique. A personalized radiographic positioner was created to standardize the images. A device was used to connect the long cone and the positioner (Fabinject FPX PADRÃO - Taubate / SP, Brazil), the positioner was modified, and three holes

were made in the occlusal support region to connect it to a vertical pin screwed to the abutment[31]. All radiographs were taken on the same X-ray machine (Figure 7).

The digitalized images in JPEG format were opened in the UTHSCSA Image Tool Software (The University of Texas Health Science Center - San Antonio / USA) for vertical and horizontal bone level measurements. First, "calibration" was performed to minimize possible radiographic distortions and generates a measurement with the greater fidelity possible from the real one, which requires knowledge of the measurement. In this work, the implant diameter was used.

For the measurement of the vertical bone level, the distance between the implant platform and the bone crest was considered by drawing a parallel line along the long axis of the implant when the implant was sub-bone. When the implant was supra-bony, a straight line was drawn from the implant platform to the first bone-implant contact point, in this case, the measurements received negative values. This procedure was performed for the mesial and distal regions and an arithmetic mean was then performed between these two values.

For horizontal measurements, a straight line was drawn perpendicular to the long axis of the implants, starting from their platform towards the bone tissue. Negative values were considered when the bone crest moved away from the implant platform. An arithmetic mean was also performed between the mesial and distal measurements to assign a single value of horizontal bone loss per implant in each evaluated period.

2.4.2 - EVALUATION OF THE CROWN-IMPLANT RATIO AND THE PROSTHETIC CROWN MESIODISTAL WIDTH:

The dimensions of the prosthetic crown are important data especially when it comes to single implants. To calculate the crown / implant ratio, the sum of the crown height measurement and the height of the "transmucosal neck of the abutment" was considered as a prosthetic lever arm and the mesiodistal width was also verified (Figure 8 and 9).

2.4.3 - STATISTICAL ANALYSIS

The Linear Regression Test was used to verify the association between the predictive variables

(crown / implant ratio, mesio-distal width, crown height) and the dependent variables (vertical bone loss and horizontal bone loss). To assess the difference between bone loss measures in the four studied periods (1, 2 3 and 4), the Analysis of Variance Test (ANOVA) and later Tukey's Test for vertical bone losses and the Kruskal Wallis test for horizontal bone losses. The tests were performed on the SigmaPlot 12.0 Software.

3 – RESULTS

A total of 20 implants were placed. Four implants with 5 mm in length and 16 implants with 6 mm in length were installed, whereas 11 where in the maxilla and 09 in the mandible. Only one implant was lost from 20 implants placed. This loss was detected during the reopening surgery. The success rate achieved over the 5-year follow-up period was 95%. The lost implant was in the region of tooth #30, still in the osseointegration phase. The patient who lost this implant had been rehabilitated in two regions, implant #19 and implant #30, both six millimeters long. Figure 10 shows the radiograph evidencing a radiolucent area surrounding the implant, characterizing non-osseointegration. Table 1 show all the demographic data of the implants placed.

Radiographic images were used to measure the peri-implant bone level and, consequently, to monitor bone loss or gain of bone in different periods. Negative values indicate supra-bone implants, that is, bone level positioned apically to the platform.

There was no bone gain in any clinical situation, neither vertical nor horizontal. It is worth remembering that the determination of the amount of bone lost for each period was done by subtracting the final bone level measurement from the bone level measurement at the beginning of the evaluated period. The change in bone level was analyzed in four different periods as mentioned in the methodology. Tables 1 and 2 show the measures of vertical and horizontal bone loss respectively in the evaluated periods and the bone loss that occurred during the total study period in all diffent evaluated proposed moment.

Analysis of variance (ANOVA) showed a statistically significant difference between the periods studied when vertical bone loss was assessed ($P < 0.001$). After that, the Tukey test showed that the statistical difference was found between Period 1 (bone loss that occurred in the post-surgical period and pre-prosthetic loading) with the other periods, 2 ($P = 0.001$), 3 ($P = 0.003$) and 4 ($P = 0.001$).

The Kruskal Wallis test showed that there was no statistically significant difference when comparing

the four periods of horizontal bone loss (P = 0.084). This test is used when there is no normal distribution of the studied values.

Data on prosthetic parameters, such as mesio-distal crown width and crown / implant ratio, were also collected. The mesio-distal width varied from 5.7 mm to 12 mm. The crown / implant ratio in all cases was greater than or equal to 1.3 with an average of 1.73 (SD = 0.31). It is worth remembering that to determine the prosthetic lever arm, the sum of the crown height and the height of the transmucosal "neck" of the abutment were used. The Linear Regression test showed that there was no statistically significant association between vertical bone loss and crown / implant ratio (P = 0.530) or mesio-distal width (P = 0.378). Besides, there was no statistically significant association between horizontal bone loss with crown / implant ratio (P = 0.591) or mesio-distal width (P = 0.968).

4 – DISCUSSION

The success rate achieved in our study over the 5-year follow-up period was 95%. Only one did not osseointegrate despite being installed by the same professional, in the same clinical session and presenting identical bone characteristics, both had type I bone, highly corticalized. The patient who lost this implant had been rehabilitated in two regions, implant #19 and implant #30, both six millimeters long. For this reason, implants with cutting characteristics on the threads and at the apex (Titamax WS Cortical) were used. We hypothesize that the probable reason for non-osseointegration was the lack of adequate blood supply to promote bone repair, characteristic of this type of bone and intensified when implants are installed with high torques [9].

The literature is controversial about the success rates for short implants, probably because there are many variables involved and that operate significantly on these indexes, such as bone type, implant surface treatment type, prosthetic connection type, surgical technique used, types of prostheses (single or multiple), diameter and what each author defines as being a short implant [1-7.]

Surface treatment seems to be one of the characteristics that most influence the success of short implants [3,4,7]. The implants studied in this work have a surface treated with oxide blasting and acid subtraction. The vast majority of studies that showed favorable indexes for short implants used implants with surface treatment[2,3,10,17,21]. The justification would be the fact that the surface treatment increases the area of

bone-implant contact, which consequently increases the values removal torque, an important feature for long-term success. Most studies that showed worse results for short implants used implants with a smooth surface[19,20]. Our results and success rates are in accordance to recent systematic reviews and literature tendency in regard to indication, surface treatment, prosthetic connection and success rates of short implants.

Studies favorable to the use of short implants smaller than 7mm a common feature was noticed in almost every system studied: abutment/implant connection type Morse taper [2,10]. These connections seem to play crucial role in reducing the incidence of mechanical complications since in the treatments with short implants the crown/implant ratio is unfavorable.

In this study, there was no loosening of the abutment despite the unfavorable crown / implant ratio, greater than or equal to 1.3 (mean of 1.73). Titamax WS implants have an internal Morse cone prosthetic connection. This connection allows for the close contact between the abutment and the implant, generating an important mechanical overlap. The frictional retention between the conical walls is responsible for retaining the abutment on the implant, ensuring its non-rotation during clinical use, a fundamental characteristic for unitary rehabilitation. In this system, bite force acts in favor of increased locking [26]. This explains the low incidence of mechanical complications found in our study. Most studies that showed worse results for short implants used systems with an external hexagonal abutment/implant connection [19,20].

Only two mechanical complications have been reported. In two cases, the prosthesis screw was loosened. In one case, this loosening could be explained by the occlusal conditions present. The patient had an anterior open bite and, as a result, the absence of anterior and lateral disocclusion guides. In addition, when in occlusion, he presented contacts only in premolars and molars. The implant tooth was in region #2 (Implant 6) and even with great care in the occlusal adjustment, it was not possible to prevent overload. A new adjustment was made and the crown screwed again without further loosening or complications on the total period evaluated. In the second case of loosening of the crown, a great rotational freedom of the crown was perceived on the abutment. This problem was probably caused by failures in the casting process or problems in the manufacture of the castable cylinder and could have been avoided if a prefabricated metal base cylinder had been used. In this case, a new crown was made and no other prosthetic problems observed.

Albrektsson et al. (1986) defined some criteria for the evaluation of success in treatments with osseointegrated implants of the Branemark System and it is still nowadays used as a parameter for success

in the literature[32]. Marginal bone loss is one of the indicators used to attest success or a tendency to failure over time [32]. In this work, bone loss in the vertical direction and bone loss in the horizontal direction were evaluated separately. The average vertical bone loss in the total 5 -year follow-up period, was 0.58 ± 0.49 mm. The greater percentage of vertical bone loss was observed in the osseointegration period, without prosthetic loading. Bone losses after loading, both horizontal and vertical, were non-significant in all the evaluated periods. Therefore, we can hypothesize that the surgical trauma during implant drilling and placement was the major cause of bone loss.

An important observation about the level of the implant surgical installation can be made. With the exception of Implants 1 (region #19) and Implant 9 (region #18), all others had vertical bone loss, ranging from 0.45mm to 1.25mm (average of 0.58mm). The implants that were installed exactly at the bone level as recommended by the system protocol started to have a smaller osseointegrated area, including the explosion of some supra-bone threads. However, the implants that were installed slightly intra-osseous are still fully submerged and therefore with a greater area of bone-implant contact. The total bone level present in the moment of implant placement did not influence the amount of marginal bone loss, but it was possible to verify that the implants placed at the bone level had a smaller area of bone / implant contact[34, 35]. Only a longer clinical follow-up and a larger amount of implants placed intra-osseous would determine whether the installation at the bone level bone represents a greater risk for the failure of Titamax WS implants in this research and in a general basis. This is an important topic to be studied in the future in regard to this specific and similar implants and protocols oriented by the manufacturer.

Short implants placement at intra-bone level requires special care in relation to osteotomy. The first bone cortex plays a critical role in primary stability, and in many cases the entire body of the implant is located solely in the medullar bone. In these cases, osteotomy should be reduced and adapted according to bone density, therefore the clinical experience of the operator is essential.

As previously shown, a significant amount of bone loss was attributed to surgical trauma, although some precautions were taken. The implants were installed by the same professional with experience in the implantology field. The learning curve is believed to significantly interfere with results, especially when using short implants. All instrumentation was performed with low rotation per minute, around 250 rpm, with new cutters and plenty irrigation, all these precautions were aimed to cause the least trauma possible to bone

tissues. Osteotomy was customized for each clinical situation taking into account the type of bone and the characteristics of the implant used, aiming at primary stability with an installation torque not exceeding 60 N/cm. In some cases of medullar bone, sub-instrumentation was used to generate primary stability, in other instances of highly corticalized bone, it was necessary to repeat the last cutter in order to reduce excessive loading torque.

A concern in dental rehabilitation with short implants, especially in single cases, is the ratio between the prosthetic crown and the implant length. Most of the time this proportion is higher than expected. For many years, a crown / root ratio ranging from 0.5 to 1 has been used in rehabilitation with fixed dental prostheses**.** In the dental case, the root fixation mechanism is the periodontal ligament, which is highly reactive to occlusal overloads. In dental implants rehabilitation, the distribution of occlusal forces has shown its own mechanisms quite different from natural teeth, probably due to the fact that there is a bone / implant "ankylosis". In this work, the influence between crown / implant ratio and the mesio / distal width of the prosthetic crown on peri-implant bone loss was verified. There was no correlation between these parameters and vertical and horizontal bone losses. The different proportions of implant length and crown as well as mesio/distal width did not had any effect on bone loss. Other studies have also attempted to show a correlation between these parameters and marginal bone loss and found no relationship between these variables [23-25].

The follow-up time after prosthetic loading was five years, indicating a good prognosis since most implant losses occur even before prosthetic loading and peri-implant bone loss is more significant in the first year[35]. Only 2 implants did not present bone loss in the evaluated period. The greater amount of bone loss found in other implants was attributed to surgical trauma and was compatible with bone loss found in other studies in the same period, even with longer implants, different abutment / implant connections and multiple cases. In other words, the use of short implants for single rehabilitations did not represent so far, a difference in the peri-implant bone tissue behavior.

All issues discussed here, such as success index, peri-implant bone loss, mechanical and biological complications, showed that the implants studied presented favorable behavior for their use even in the studied clinical situation. However, it remains to be seen whether these results will be sufficient to maintain long-term success rates.

5 - CONCLUSION

The short implants studied in this work used in single rehabilitation showed a success rate greater than or equal to the indexes found for longer length implants found in the literature. In addition, the level of bone loss found was also within the normal range when compared to other clinical studies regardless of the length of the implants. The different proportions of implant length and crown as well as mesio/distal width did not had any effect on bone loss. It is suggested that for this type of implant, internal morse connection is favorable. The placement of the Neodent WS implants (and similar implants) in an intra-osseous protocol and not at bone level needs further investigation because it might present better results in regard to vertical bone loss over time.

ACKNOWLEDGMENT

I am very grateful to my advisor Maria da Glória Chiarello de Mattos (in memorian) for her teachings as a researcher in the FORP / USP Graduate Program and as a magnificent example of a human being. Without your support and trust this work would not have been possible.

REFERENCES

1. Fan T, Li Y, Deng WW, Wu T, Zhang W. Short Implants (5 to 8 mm) Versus Longer Implants (>8 mm) with Sinus Lifting in Atrophic Posterior Maxilla: A Meta-Analysis of RCTs. *Clin Implant Dent Relat Res.* 2017;19:207-215
2. Fugazzotto PA. Shorter implants in clinical practice: rationale and treatment results. *Int J Oral Maxillofac Implants.* 2008;23:487-96.
3. Fernandes GVO, Costa BMGN, Trindade HF, Castilho RM, Fernandes JCH. Comparative analysis between extra-short implants (≤6 mm) and 6 mm-longer implants: a meta-analysis of randomized controlled trial. *Aust Dent J.* 2022 doi: 10.1111/adj.12900. Article In Press

4. Vetromilla BM, Mazzetti T, Pereira-Cenci T. Short versus standard implants associated with sinus floor elevation: An umbrella review of meta-analyses of multiple outcomes. *J Prosthet Dent.* 2021;126:503-511.
5. Misch CE, Steignga J, Barboza E, Misch-Dietsh F, Cianciola LJ, Kazor C. Short dental implants in posterior partial edentulism: a multicenter retrospective 6-year case series study. *J Periodontol.* 2006;77:1340-1347.
6. Neves FD, Fones D, Bernardes SR, do Prado CJ, Neto AJ. Short implants--an analysis of longitudinal studies. *Int J Oral Maxillofac Implants.* 2006;21:86-93.
7. Pauletto P, Ruales-Carrera E, Mezzomo LA, Stefani CM, Taba-Junior M, Gonçalves RB, Flores-Mir C, Canto GL. Clinical performance of short versus standard dental implants in vertically augmented bone: an overview of systematic reviews. *Clin Oral Investig.* 2021;25:6045-6068.
8. Vasco MAA, Hecke MB, Bezzon OL. Analysis of Short Implants and Lateralization of the Inferior Alveolar Nerve With 2-Stage Dental Implants by Finite Element Method. *J Craniofac Surg.* 2011;22:2064-2071.
9. Stellingsma C, Vissink A, Meijer HJ, Kuiper C, Raghoebar GM. Implantology and the severely resorbed edentulous mandible. *Crit Rev Oral Biol Med.* 2004;15:240-248.
10. Arlin ML. Short dental implants as a treatment option: results from an observational study in a single private practice. *Int J Oral Maxillofac Implants*. 2006;21:769-276.
11. Esposito M, Cannizzaro G, Soardi E, Pistilli R, Piatelli M, Corvino V, Felice P. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm-long, 4 mm-wide implants or by longer implants in augmented bone. Preliminary results from a pilot randomised controlled trial. *Eur J Oral Implantol*. 2012;5(1):19–33.
12. Felice P, Pistilli R, Piattelli M, Soardi E, Corvino V, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 5 x 5mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. Preliminary results from a randomized controlled trial. *Eur J Oral Implantol.* 2012;5:149-161.

13. Felice P, Soardi E, Pellegrino G, Pistilli R, Marchetti C, Gessaroli M, Esposito M. Treatment of the atrophic edentulous maxilla: short implants versus bone augmentation for placing longer implants. Five-month post-loading results of a pilot randomised controlled trial. *Eur J Oral Implantol.* 2011;4:191–202.
14. Sánchez-Garcés MA, Costa-Berenguer X, Gay-Escoda C. Short implants: a descriptive study of 273 implants. *Clin Implant Dent Relat Res.* 2012;14:508-516.
15. Srinivasan M, Vazquez L, Rieder P, Moraguez O, Bernard JP, Belser UC. Efficacy and Predictability of Short Dental Implants (< 8 mm): A Critical Appraisal of the Recent Literature. *Int J Oral Maxillofac Implants.* 2012;27:1429–1437.
16. Monje A, Chan HL, Fu JH, Suarez F, Galindo-Moreno P, Wang HL. Are short dental implants (<10mm) effective? Meta-Analysis on Prospective Clinical Trial. *J Periodontol.* 2013;84:895-904.
17. Mertens C, Meyer-Baumer A, Kappel H, Hoffmann J, Steveling HG. Use of 8-mm and 9-mm Implants in Atrophic Alveolar Ridges: 10-Year Results. *Int J Oral Maxillofac Implants*. 2012;27:1501–1508.
18. Schierano G, Canuto RA, Navone R, Peirone B, Martinasso G, Pagano M, Maggiora M, Manzella C, Easton M, Davit A, Trombetta A, Amedeo S, Biolatti B, Carossa S, Preti G. Biological factors involved in the osseointegration of oral titanium implants with different surfaces: a pilot study in minipigs. *J Periodontol.* 2005;76:1710-1720.
19. Naert I, Koutsikakis G, Duyck J, Quirynen M, Jacobs R, van Steenberghe D. Biologic outcome of implant-supported restorations in the treatment of partial edentulism part I: a longitudinal clinical evaluation. *Clin Oral Implants Res.* 2002;13:381-389.
20. Weng D, Jacobson Z, Tarnow D, Hürzeler MB, Faehn O, Sanavi F, Barkvoll P, Stach RM. A prospective multicenter clinical trial of 3i machined-surface implants: results after 6 years of follow-up. *Int J Oral Maxillofac Implants.* 2003;18:417-423.
21. Perelli M, Abundo R, Corrente G, Saccone C. Short (5 and 7 mm long) porous implants in the posterior atrophic maxilla: a 5-year report of a prospective single-cohort study. *Eur J Oral Implantol.* 2012;5:265–272.
22. Blanes RJ. To what extent does the crow-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. *Clin Oral Impl Res.* 2009;20:67-72.

23. Rokni S, Todescan R, Watson P, Pharoah M, Adegbembo AO, Deporter D. An assessment of crown-to-root ratios with short sintered porous-surfaced implants supporting prostheses in partially edentulous patients. *Int J Oral Maxillofac Implants.* 2005;20:69-76.

24. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. *Int J Oral Maxillofac Implants.* 2006;21:275-282.

25. Urdaneta RA, Rodriguez S, McNeil DC, Weed M, Chuang SK. The effect of increased crown-to-implant ratio on single-tooth locking-taper implants. *Int J Oral Maxillofac Implants.* 2010;25:729-743.

26. Bozkaya D, Müftü S. Mechanics of the tapered interference fit in dental implants. *J Biomech.* 2003;36:1649-1058.

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

28. Carvalho NA, Almeida EO, Rocha EP, Freita Jr AC, Anchieta RB, Kina S. Short Implant to Support Maxillary Restorations: Bone Stress Analysis Using Regular and Switching Platform. *J Craniofac Surg.* 2012;23:678-681.

29. Anitua E, Orive G. Short Implants in Maxillae and Mandibles: A Retrospective Study With 1 to 8 Years of Follow-Up. *J Periodontol.* 2010;81:819-826.

30. Atieh MA, Zadeh H, Stanford CM, Cooper LF. Survival of Short Dental Implants for Treatment of Posterior Partial Edentulism: A Systematic Review. *Int J Oral Maxillofac Implants.* 2012;27:1323–1331.

31. Sartori IAM, Silveria-Junior CD, Fontão FN, Mattos MGC. Evaluation of radiographic technique using a new customized film holder for dental implant assessment. *Implant Dent.* 2014;23:13-17.

32. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants.* 1986;1:11-25.

33. Barros RR, Novaes AB Jr, Muglia VA, Iezzi G, Piattelli A. Influence of interimplant distances and placement depth on peri-implant bone remodeling of adjacent and immediately loaded Morse cone connection implants: a histomorphometric study in dogs. *Clin Oral Implants Res.* 20101;21:371-378.

34. Weng D, Nagata MJ, Bell M, Bosco AF, de Melo LG, Richter EJ. Influence of microgap location and configuration on the periimplant bone morphology in submerged implants An experimental study in dogs. *Clin Oral Implants Res.* 2008;19:1141-1147.

35. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. *J Prosthet Dent.* 2003;90:121-132.

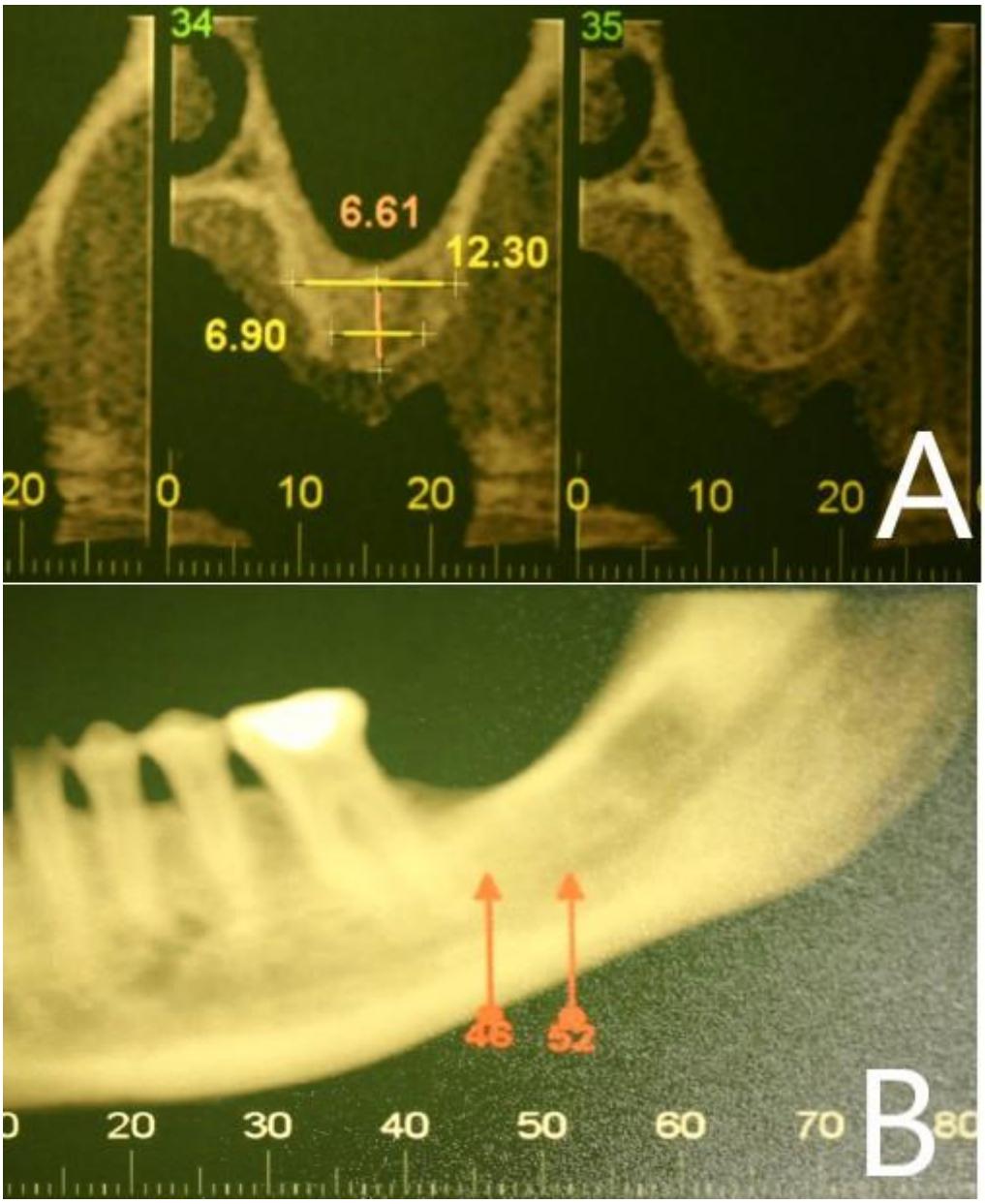


Figure 1. Some of the surgical steps and initial planning. A and B. Tomographic image of a atrophic maxilla and mandible candidate to receive a short implant

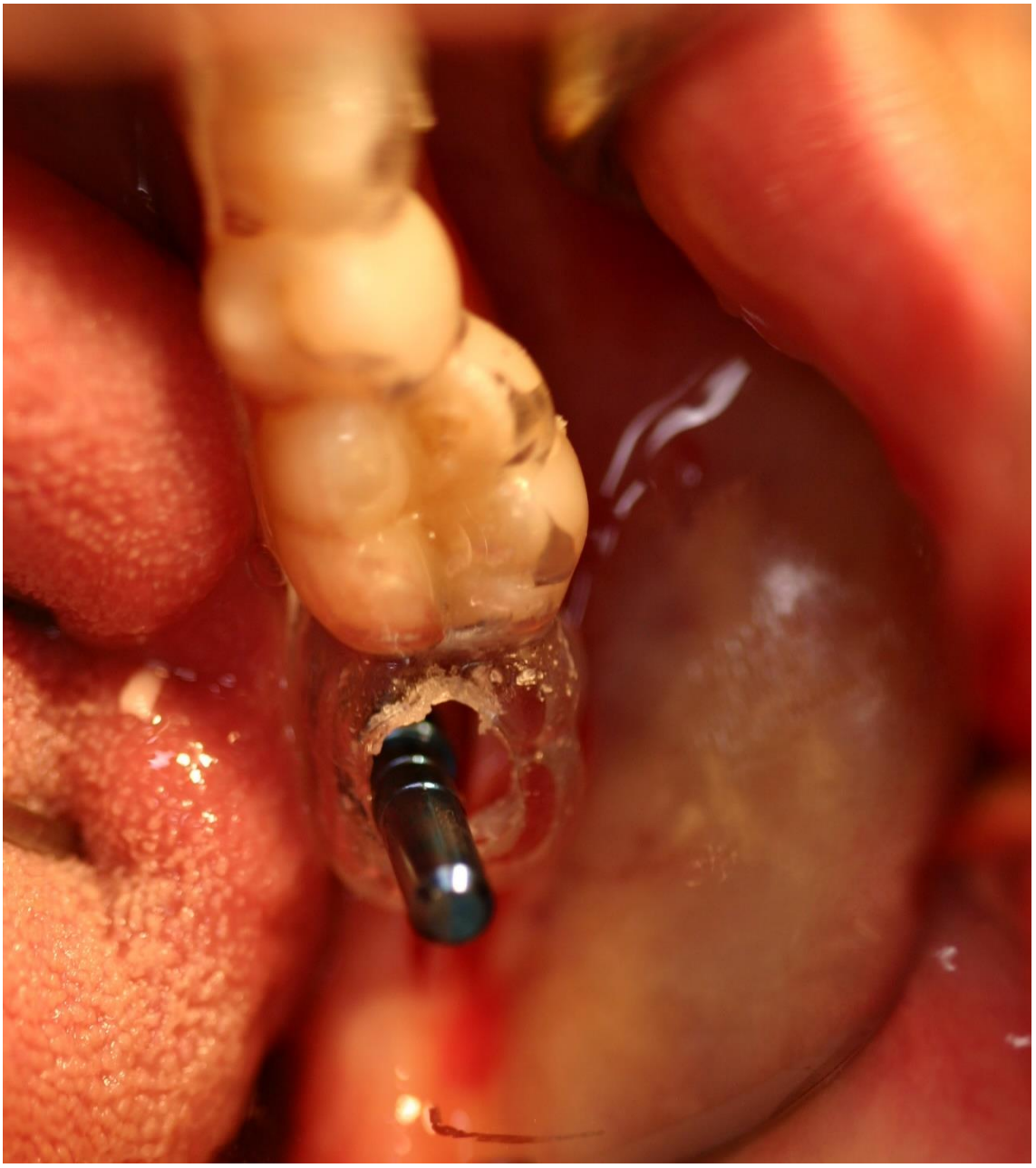


Figure 2. All implants were inserted with a surgical guide to ensure correct emergence of the implant and prosthesis

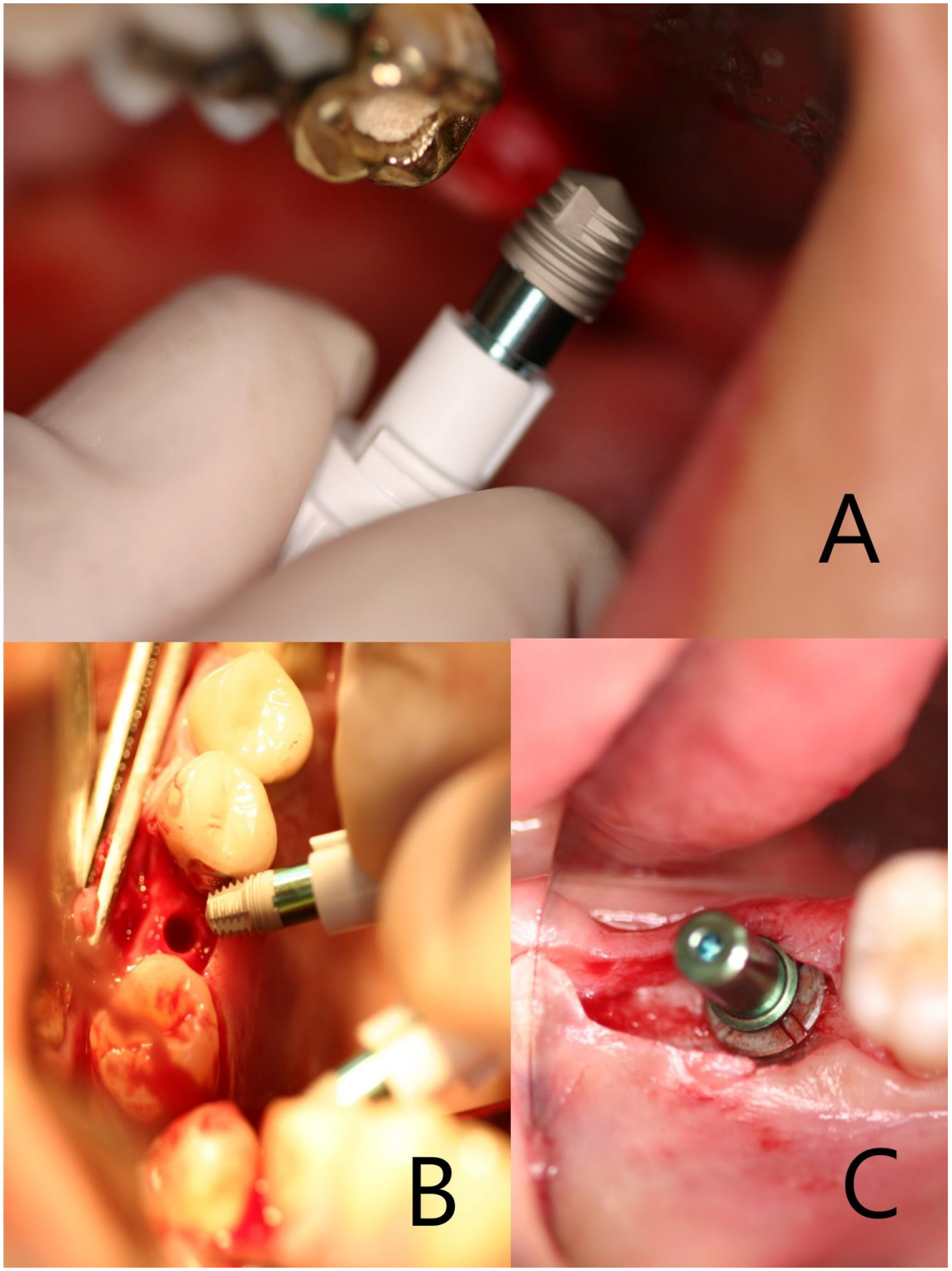


Figure 3. Placement of the WS Neodent Short Implant. A. Neodent WS Short Impalnt. B. Manual placement of the WS Implant. C. Final and adequate position of the short implant.

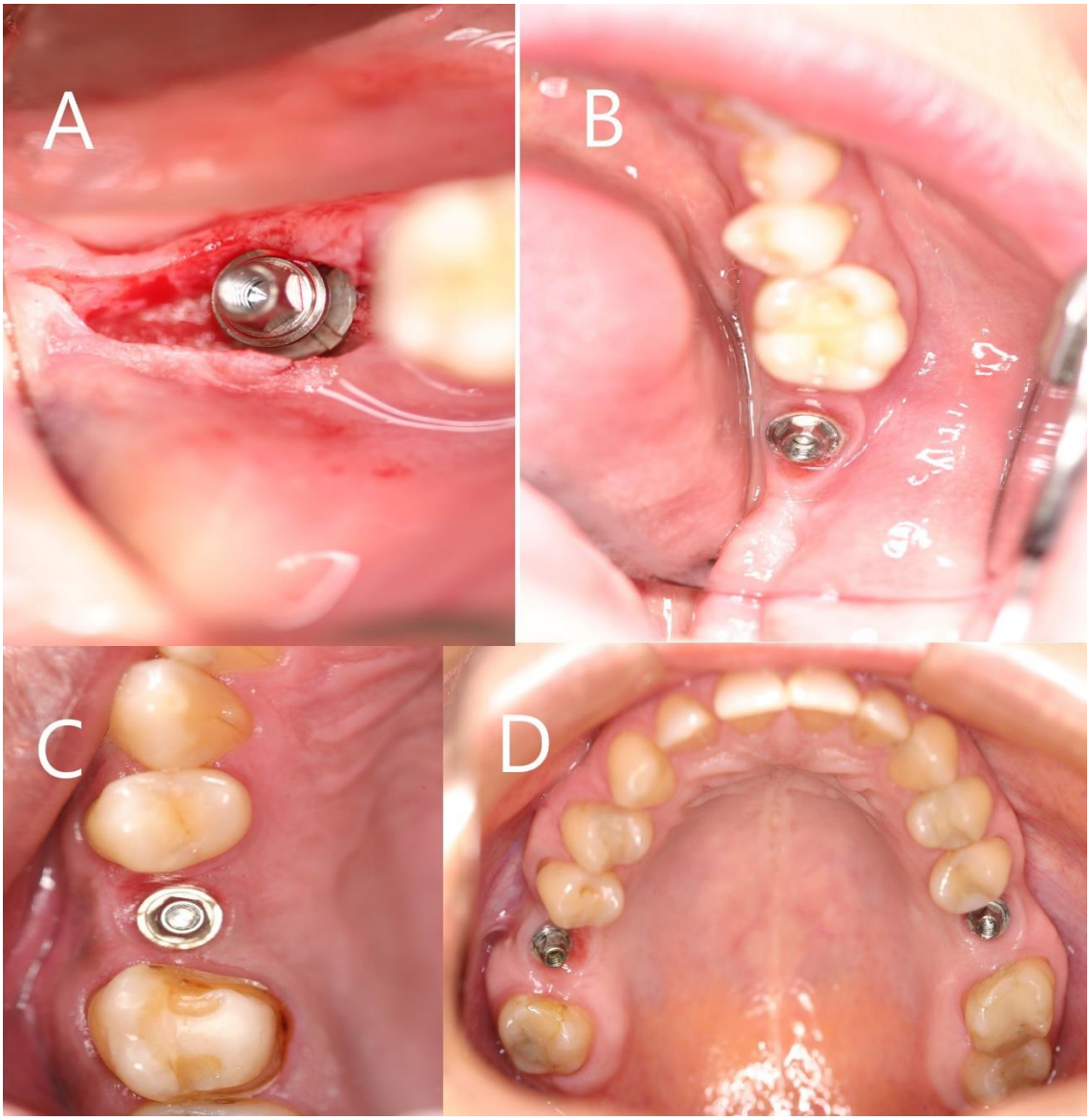


Figure 4. A 2º step 'reopening' of the implant after 4 month osseintegration period. B. 3 weeks after healing period with the abutment protection cylinders in postion. C. Another patient 3 weeks after 2o step and 3 week healing period. D. Patient Y 3 weeks after 2o step and 3 week healing period.

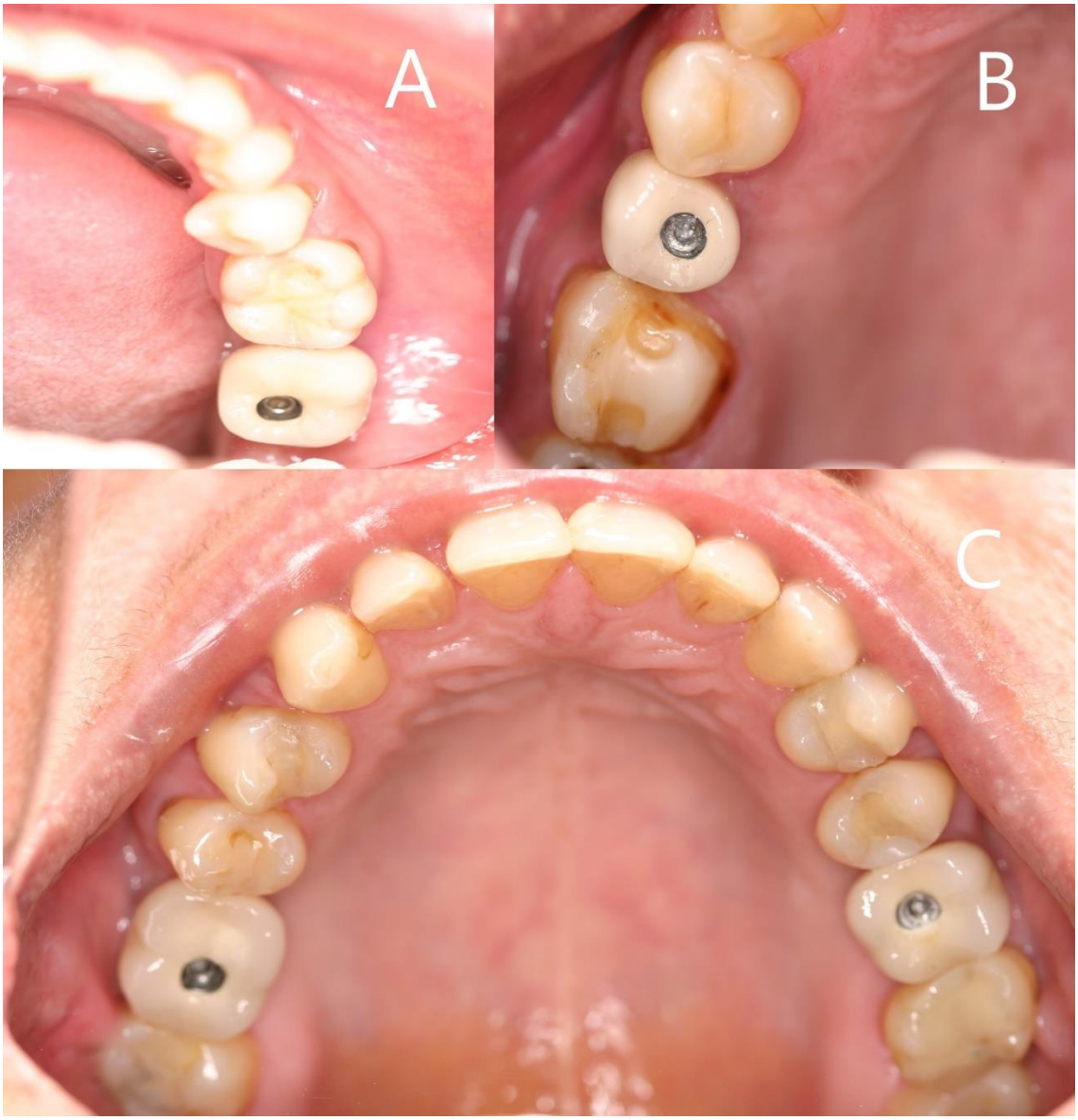


Figure 5. Final restorations. A, B, C ilustrate the initial adaptation of the final restorations of the infrastructre and if necessary, adjstments were made. D, E, F. Final Glazed surface and definitely installation of the implant prosthesis.

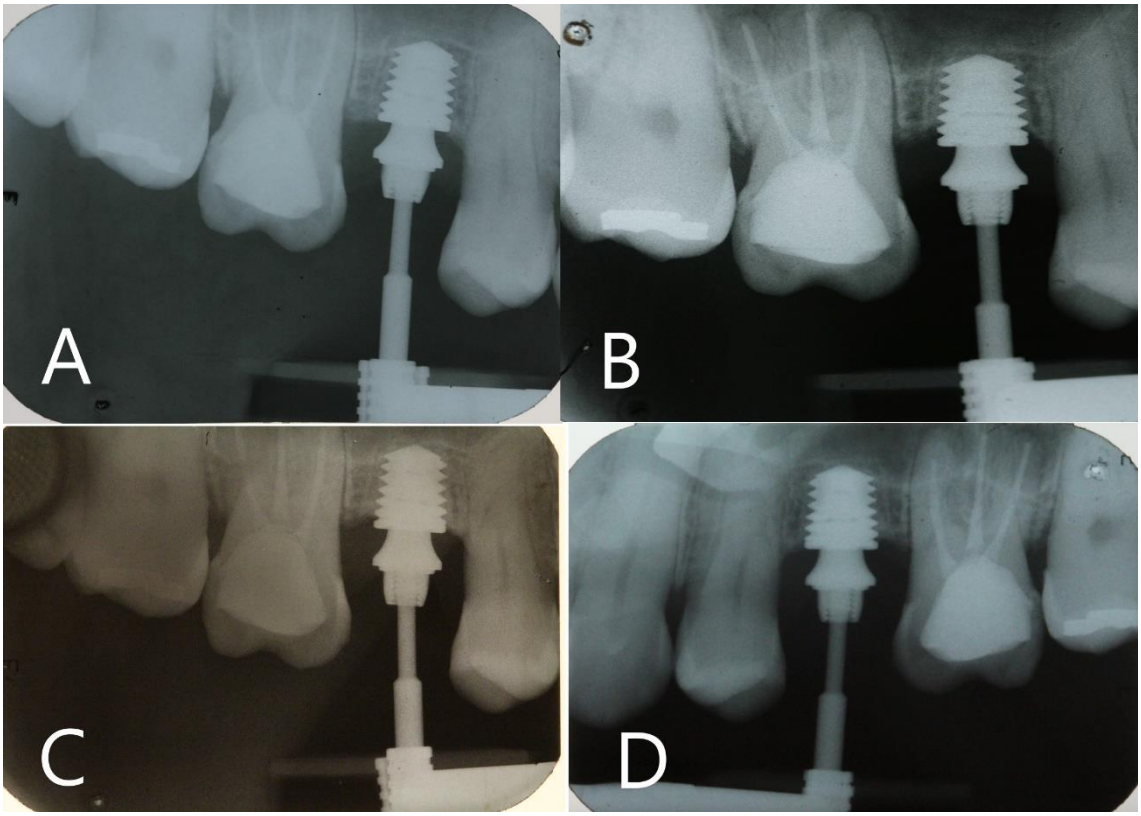


Figure 6. Radiographic Image. A. T1 Immediate post-operative follow-up. Figure 6. Radiographic Image. B. T2 1 year follow-up. Figure 6. Radiographic Image. C. T3 3 year follow-up. Figure 6. Radiographic Image. D. T4 5 year follow-up.

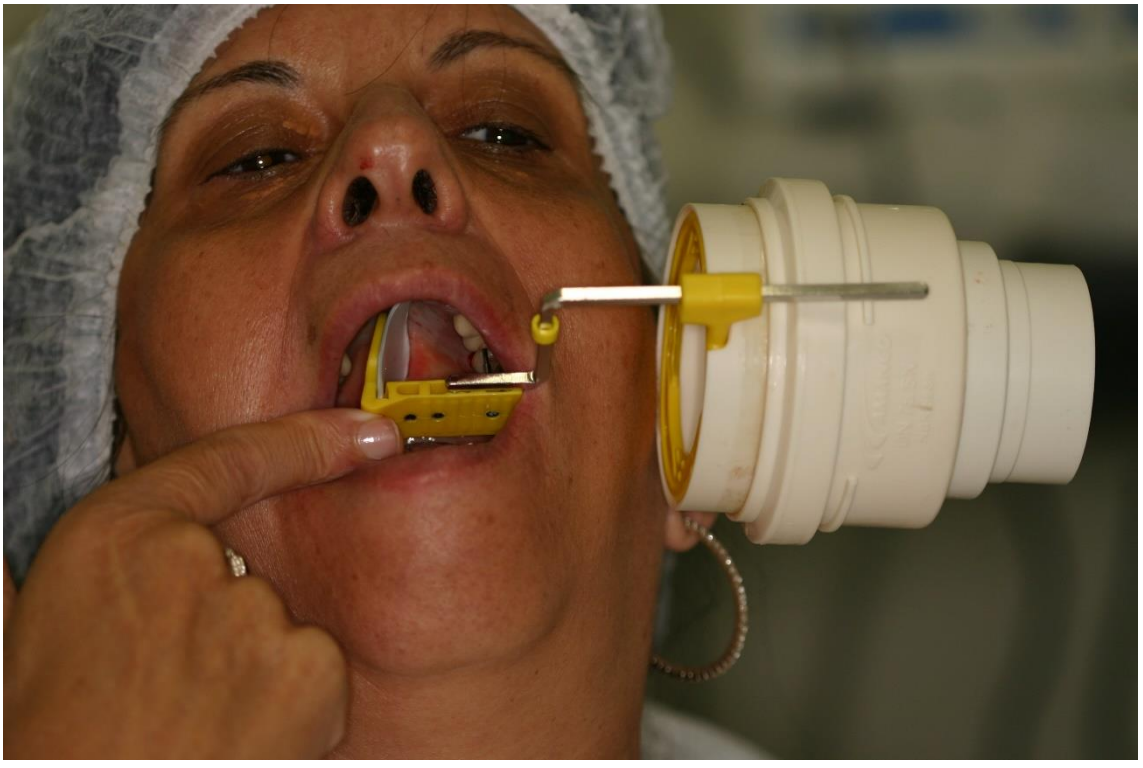


Figure 7. The personalized radiographic positioner and its modifications.

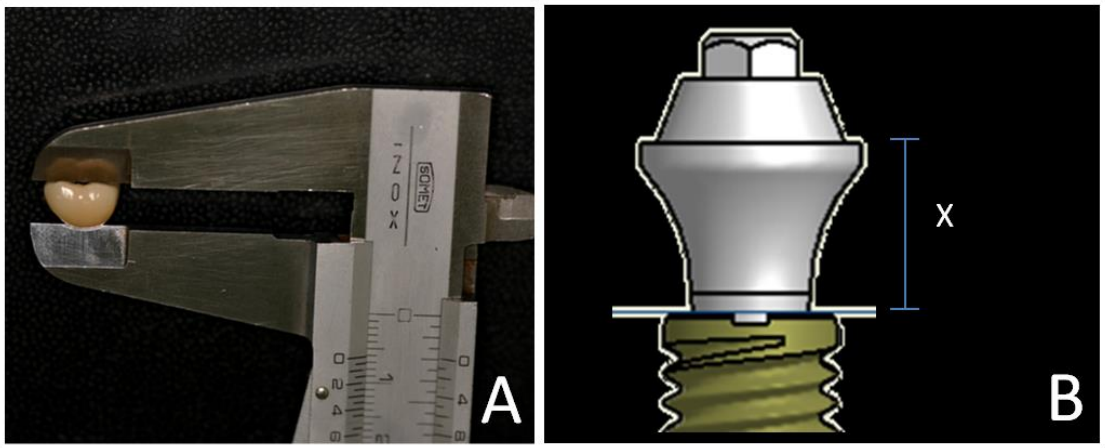


Figure 8. Determination of the prosthetic lever arm, i.e. the sum of A: measurement of the vertical height of the crown and B: the height of the transmucosal neck of the abutment

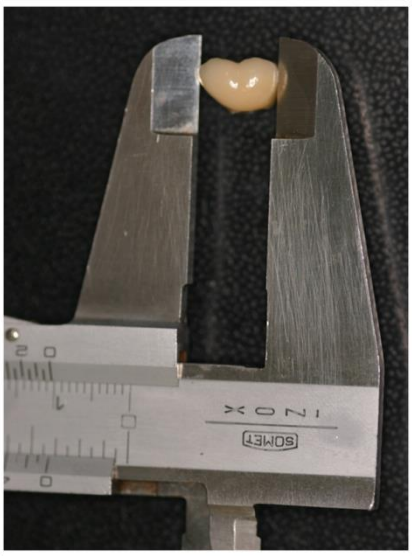


Figure 9. Mesiodistal width was also verified

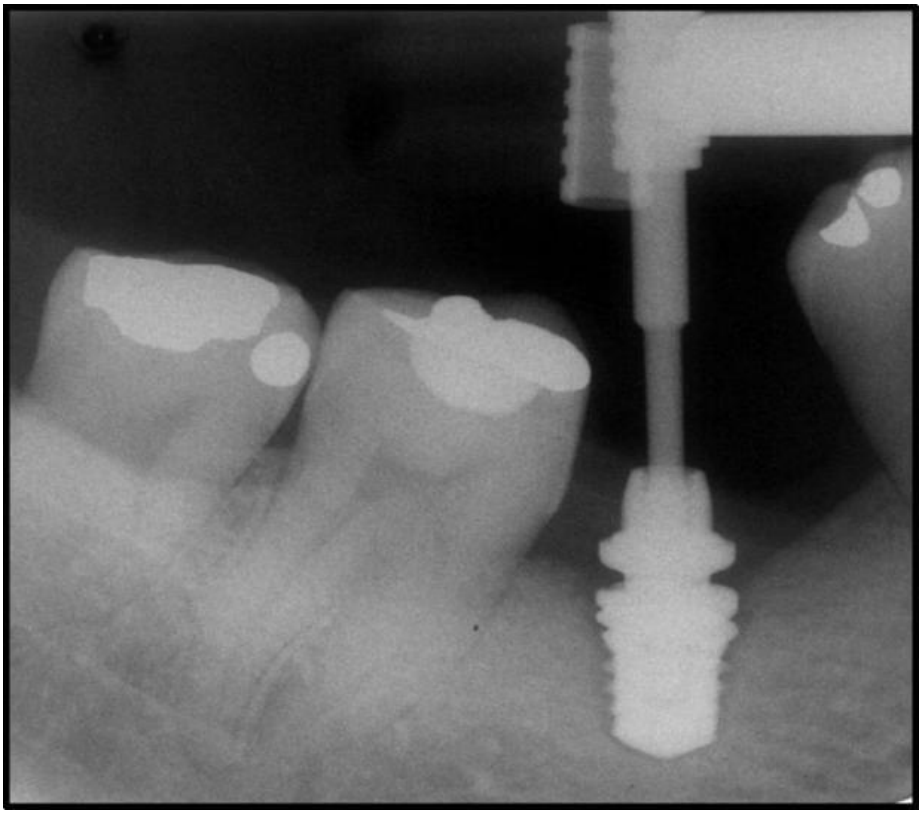


Figure 10– radiograph evidencing a radiolucent area surrounding the implant, characterizing non-osseointegration.

Table 1. Demographic data from all 20 implants installed in 18 patients.

Patient Age/Gender	Implant tooth site	Implant size	Total Vertical bone loss	Total Horizontal bone loss	Crown / Implant Ratio	Mesio-Distal Crown width
GCM 54y / F	19	5 x 5 mm	0,33	0	1,9	10
GCM 54y / F	29	5 x 5 mm	-0,84	-0,53	2,1	7,6
IVM 47y / M	14	5 x 6 mm	-1,18	-0,17	2,2	7
JC 55y / M	19	6 x 6 mm	-0,89	-0,25	1,8	6,5
JCS 50y / M	2	5 x 6 mm	-1,02	-0,83	1,6	7
KTQ 27y / F	3	5 x 6 mm	-0,64	0	1,8	9
KSQ 30y / F	14	5 x 6 mm	-1,09	-0,77	1,3	10
MAB 55y / F	18	5 x 6 mm	0,28	0	1,8	8
VAC 55y / F	19	5 x 5 mm	-0,43	-0,04	2,5	8,3
APC 45y / F	18	6 x 6 mm	0,30	0,64	1,7	9,5
APQ 23y / F	13	5 x 6 mm	-0,49	0	1,4	6
EFA 32y / M	13	5 x 6 mm	-0,39	0	1,8	7
KQO 31y / F	20	5 x 6 mm	-0,27	-0,59	1,8	7,5
MAF 60y / F	14	4 x 6 mm	-0,69	0	1,3	5,7
MRR 47y / F	13	5 x 6 mm	-1,21	0	1,4	6
MAP 41y / F	15	5 x 6 mm	-0,44	-0,24	1,8	9

MAG 45y / F	3	5 x 6 mm	-1,25	-0,81	1,5	9
MAG 45y / F	14	5 x 5 mm	-0,69	0	1,9	12
OSS 50y / M	20	5 x 6 mm	-0,45	0	1,6	8
Mean results for evaluated data			-0,58 mm	-0,19 mm	1,73 mm	8,06 mm
Standard Deviation			0,49	0,37	0,31	1,64

y: Years (age); **F:** Female; **M:** Male; **mm:** milimmeters

Table 2. Peri-implant Vertical Bone Loss in all periods evaluated, from surgery to 5 year follow-up.

Peri-implant Vertical Bone Loss						
		Period 1	**Period 2**	**Period 3**	**Period 4**	**Total period**
	Implant tooth site	**From surgery to final prosthesis**	**Prosthesis to 1-year follow-up**	**Prosthesis to 3-year follow-up**	**Prosthesis to 5-year follow-up**	**From surgery to 5 year follow-up**
Patient Age/Gender						
GCM 54y / F	19	-0,24	0,46	0,57	0,57	0,33
GCM 54y / F	29	-0,62	0,06	-0,02	-0,22	-0,84
IVM 47y / M	14	-1,14	0,30	0,53	-0,04	-1,18
JC 55y / M	19	-0,67	-0,70	-0,73	-0,22	-0,89
JCS 50y / M	2	-1,16	0,08	0,24	0,14	-1,02
KTQ 27y / F	3	-0,04	-0,53	0,10	-0,60	-0,64
KSQ 30y / F	14	-0,52	-1,12	-0,98	-0,57	-1,09
MAB 55y / F	18	0,53	-0,60	-0,13	-0,25	0,28
VAC 55y / F	19	-0,6	-0,17	-0,11	0,17	-0,43
APC 45y / F	18	-0,53	0,67	0,67	0,23	0,30
APQ 23y / F	13	-0,14	0,22	-0,49	-0,63	-0,49
EFA 32y / M	13	-1,13	0,37	0,84	0,74	-0,39
KQO 31y / F	20	-0,42	0,23	-1,10	0,69	-0,27
MAF 60y / F	14	-0,61	-0,3	-0,08	-0,08	-0,69
MRR 47y / F	13	-1,17	0,31	0,43	-0,04	-1,21
MAP 41y / F	15	-0,35	-0,28	-0,39	-0,09	-0,44
MAG 45y / F	3	-1,2	0,36	0,09	-0,05	-1,25
MAG 45y / F	14	-0,89	0,39	0,07	0,20	-0,69
OSS 50y / M	20	-0,37	0,16	-0,23	0,08	-0,45
Mean		-0,59	0,00	-0,04	0,00	-0,58
Standard Deviation		0,46	0,47	0,54	0,39	0,49

y: Years (age); **F:** Female; **M:** Male; **mm:** milimmeters

Table 3. Peri-implant Horizontal Bone Loss in all periods evaluated, from surgery to 5 year follow-up.

Peri-implant Vertical Bone Loss						
		Period 1	**Period 2**	**Period 3**	**Period 4**	**Total period**
	Implant tooth site	**From surgery to final prosthesis**	**Prosthesis to 1-year follow-up**	**Prosthesis to 3-year follow-up**	**Prosthesis to 5-year follow-up**	**From surgery to 5 year follow-up**
Patient Age/Gender						
GCM 54y / F	19	0	0	0,00	0	0,00
GCM 54y / F	29	0	0	0,00	-0,53	-0,53
IVM 47y / M	14	0	0	0,00	-0,17	-0,17
JC 55y / M	19	0	0	-0,83	-0,25	-0,25
JCS 50y / M	2	-1,26	0,63	-1,26	0,43	-0,83
KTQ 27y / F	3	0	0	0,00	0	0,00
KSQ 30y / F	14	-0,44	-0,22	-0,33	-0,33	-0,77
MAB 55y / F	18	0	0	0,00	0	0,00
VAC 55y / F	19	-0,58	-0,29	-0,16	0,54	-0,04
APC 45y / F	18	0	0	0,00	0,64	0,64
APQ 23y / F	13	0	0	0,00	0	0
EFA 32y / M	13	-1,27	1,06	1,27	1,27	0
KQO 31y / F	20	-0,67	0,05	0,12	0,08	-0,59
MAF 60y / F	14	0	-0,36	0,00	0	0
MRR 47y / F	13	-0,29	0,11	0,04	-0,29	0
MAP 41y / F	15	0	0	-0,14	-0,24	-0,24
MAG 45y / F	3	-1,15	0,36	0,51	-0,34	-0,81
MAG 45y / F	14	0	0	0,00	0	0
OSS 50y / M	20	-0,54	-0,37	-0,03	0,54	0
Mean		-0,33	0,05	-0,04	0,07	-0,19
Standard Deviation		0,46	0,33	0,49	0,44	0,37

y: Years (age); **F:** Female; **M:** Male; **mm:** milimmeters

CONCLUSÕES

4. CONCLUSÕES

Dentro das limitações clínicas e do número de pacientes, mas principalmente pelo tempo reduzido de acompanhamento que precisou ser adaptado para os pacientes desta pesquisa, pode-se concluir que:

Esta tese de doutorado teve objetivo avaliar o impacto do tratamento com o apoio de Próteses parciais removíveis inferiores sobre cicatrizadores sobre implantes dentários afim de se dividir a sobrecarga mastigatória e melhorar o tratamento como um todo. Esse objetivo foi atingido e comprovado, pois os testes de performance mastigatória, através de habilidade de mistura e força máxima de mistura tiveram resultados positivos/melhorados estatisticamente significativos. Além disso, as perguntas acerca de tópicos de limitação funcional e dor melhoraram significativamente, superando alguns dos incômodos do paciente Classe I de Kennedy.

Durante a pesquisa inicial e revisão de literatura para a tese, observou-se a ausência de padrão e definições claras acerca dos métodos de performance mastigatória. Não havia até aquele momento, publicações relevantes com clara associação do alimento teste com a sua forma de avaliação, as nomenclaturas eram confusas, e não havia padronização de teste para perfil de paciente ou tratamentos. O trabalho de revisão crítica da literatura auxilia na orientação e guia para os métodos de performance mastigatória e levando em conta as suas vantagens e desvantagens, para pacientes edêntulos totais ou parciais, com tratamentos removíveis, indica-se os testes com goma de mascar, no caso, teste de habilidade de mistura.

Os implantes curtos ainda foram testados em outro estudo de forma individual com resultados satisfatórios e semelhantes a implantes convencionais, mesmo com próteses em proporções não ideais quando relacionada prótese-implante.

Sendo assim, acredito que este trabalho principal e os seus desdobramentos, efetiva mais uma opção para um grande número de pacientes (a transformação em Classe III de Kennedy através de um implante e cicatrizador), especialmente em um país que além de ter um alta quantidade de pacientes edêntulos, pacientes com inviabilidade econômica para reabilitação completa com implantes dentários, e também evitar reconstruções complexas previamente aos implantes. Além disso, o

perfil de pacientes edêntulos idosos tem aumentado, favorecendo a filosofia da implantodnotia moderna de buscar tratamentos menos invasivos, com menor tempo de tratamento, custos e morbidade associadas, mantendo-se uma boa previsibilidade.

RERERÊNCIAS

5. REFERÊNCIAS

1. Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg. 1981;10(6):387-416. https://doi.org/10.1016/S0300-9785(81)80077-4
2. Attard NJ, Zarb GA. Implant prosthodontic management of partially edentulous patients missing posterior teeth: the Toronto experience. J Prosthet Dent. 2003;89(4):352-9. https://doi.org/10.1067/mpr.2003.91 PMid:12690347
3. Boretti G, Bickel M, Geering AH. A review of masticatory ability and efficiency. J Prosthet Dent. 1995;74(4):400-3. https://doi.org/10.1016/S0022-3913(05)80381-6
4. Borges TF, Mendes FA, Oliveira TRC, Prado CJ, Neves FD. Overdenture with immediate lad: mastication and nutrition. British Journal of Nutrition. 2011;1-6.
5. Branemark PI, Hansson BO, Adell R, Breine U, Lindstrom J, Hallen O, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg Suppl. 1977;16:1-132.
6. Campos CL, Gonçalves TMSV, Garcia RCMR. Implant retainers for free-end removable partial dentures affect mastication and nutrient intake. Clin. Oral Impl. Res. 25, 2014, 957-961 https://doi.org/10.1111/clr.12165 PMid:23560748
7. Christensen GJ. Removable prosthodontics: a forgotten part of dentistry. Alpha Omegan. 2006;99(1):26-8. https://doi.org/10.1016/j.aodf.2006.02.028 PMid:16865850
8. Cunha LD, Pellizzer EP, Verri FR, Falcon-Antenucci RM, Goiato MC. Influence of ridge inclination and implant localization on the association of mandibular Kennedy class I removable partial denture. J Craniofac Surg. 2011;22(3):871-5. https://doi.org/10.1097/SCS.0b013e31820f7d6a PMid:21558932
9. Escudeiro Santos C, Freitas O, Spadaro SCC, Mestriner Junior W. Development of a colorimetric system for evaluation of the masticatory efficiency. Braz Dent J. 2006;17(2):95-9. https://doi.org/10.1590/S0103-64402006000200002 PMid:16924334
10. Gonçalves TMSV, Campos CL, Gonçalves GM, Moraes M, Garcia RCMR. Mastication Improvement After Partial Implant-supported Prosthesis Use. J Dent Res. 2013 Dec;92(12 Suppl):189S-94S https://doi.org/10.1177/0022034513508556 PMid:24158344 PMCid:PMC3860066
11. Gonçalves TMSV, Campos CL, Garcia RCMR. Implant retention and support for distal extension partial removable dental prostheses: Satisfaction outcomes. J Prosthet Dent. 2014 Aug;112(2):334-9 https://doi.org/10.1016/j.prosdent.2013.11.004 PMid:24513426
12. Grossmann Y, Nissan J, Levin L. Clinical effectiveness of implant-supported removable partial dentures: a review of the literature and retrospective case evaluation. J Oral Maxillofac Surg. 2009;67(9):1941-6. https://doi.org/10.1016/j.joms.2009.04.081 PMid:19686933
13. Kuzmanovic DV, Payne AG, Purton DG. Distal implants to modify the Kennedy classification

of a removable partial denture: a clinical report. J Prosthet Dent. 2004;92(1):8-11. https://doi.org/10.1016/j.prosdent.2004.04.010 PMid:15232557

14. Liu R, Kaleinikova Z, Holloway JA, Campagni WV. Conversion of a Partial Removable Dental Prosthesis from Kennedy Class II to Class III Using a Dental Implant and Semiprecision Attachments. J Prosthodont. 2011; https://doi.org/10.1111/j.1532-849X.2011.00769.x PMid:21985475
15. Mendonca DB, Prado MM, Mendes FA, Borges Tde F, Mendonca G, do Prado CJ, et al. Comparison of masticatory function between subjects with three types of dentition. Int J Prosthodont. 2009;22(4):399-404.
16. Mitrani R, Brudvik JS, Phillips KM. Posterior implants for distal extension removable prostheses: a retrospective study. Int J Periodontics Restorative Dent. 2003;23(4):353-9.
17. Ohkubo C, Kobayashi M, Suzuki Y, Hosoi T. Effect of implant support on distal-extension removable partial dentures: in vivo assessment. Int J Oral Maxillofac Implants. 2008;23(6):1095-101.
18. Oliveira TRC, Freitas TF, Mendes FA, Neves FD. Risk of malnutrition in completely edentulous individuals. In: Malnutrition in the 21st Century. 2008;1(265-80.
19. Prado MMS, Freitas TF, Prado CJ, Gomes VL, Neves FD. Função mastigatória de indivíduos reabilitados com próteses totais mucoso suportadas. Pesquisa Brasileira em Odontopediatria e Clínica Integrada. 2006;6(259-66.
20. Silva MO, Zancope K, Mestriner Junior W, Prado CJ, Neves FD, Simamoto Junior PC. Mastigatory function avaluation by two methods: colorimetry and sifters. Rev Odontol Bras Central. 2011;20(53):125-8.
21. Verri FR, Pellizzer EP, Pereira JA, Zuim PR, Santiago Junior JF. Evaluation of bone insertion level of support teeth in class I mandibular removable partial denture associated with an osseointegrated implant: a study using finite element analysis. Implant Dent. 2011;20(3):192-201. https://doi.org/10.1097/ID.0b013e3182166927 PMid:21613946
22. Wismeijer D, Tawse-Smith A, Payne AG. Multicentre prospective evaluation of implant-assisted mandibular bilateral distal extension removable partial dentures: Patient satisfaction. Clin Oral Implants Res. 2011. https://doi.org/10.1111/j.1600-0501.2011.02367.x PMid:22111809
23. Witter DJ, Van Elteren P, Kayser AF, Van Rossum GM. Oral comfort in shortened dental arches. J Oral Rehabil. 1990;17(2):137-43. https://doi.org/10.1111/j.1365-2842.1990.tb01402.x PMid:2187971