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Instalação de coroas implantadas distais para modificação da classificação de pacientes classe I para classe III de Kennedy

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

Uberlândia, 2014

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DEDICATÓRIA

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“Se vi mais longe... é porque me apoiei nos ombros de gigantes”
Isaac Newton

SUMÁRIO

RESUMO

A perda de elementos dentários causa desarmonia no aparelho estomatognático, principalmente quando essas perdas ocorrem bilateralmente na região posterior da mandíbula. Para esses casos, as Próteses Parciais Removíveis de Extremidade Livre (PPREL) são as mais amplamente utilizadas, uma vez que possuem baixo custo de execução e não necessitam de procedimentos cirúrgicos para sua realização. Contudo, esse tipo de prótese é a que possui pior prognóstico, uma vez que durante a mastigação ocorre movimento de intrusão da prótese em direção ao rebordo e ao assoalho de boca, com consequente reabsorção óssea e perda da estabilidade e suporte da prótese. Para resolver essa questão, desde o início dos anos 90 é proposto a colocação de um implante na região mais posterior possível da mandíbula para servir como anteparo à PPREL. Porém, a literatura não descreve qual seria o melhor intermediário a ser utilizado; tampouco qual é o impacto do tratamento proposto para o dente pilar da PPREL. O objetivo desse trabalho foi avaliar o impacto da instalação de implante distal para suportar ou reter PPREL em pacientes classe I de Kennedy. Primeiramente, foi realizada revisão sistemática sobre o assunto, para avaliar a literatura recente. Em seguida, foi realizado estudo empregando Fotoelasticidade de Transmissão Plana para avaliar distribuição de tensões ao redor do dente pilar e implante para compreender a influência do tipo de conexão do implante (interna ou externa) e do tipo de dispositivo sobre implante (coroa ou *attachment*) para suportar uma PPR. Finalmente, avaliou-se a distribuição de tensões, por meio de Análise de Elementos Finitos, ao redor do dente e de diferentes tamanhos de implante distal para suportar uma PPREL associado a coroa metálica sobre implante. De acordo com os resultados obtidos no presente estudo, pode-se concluir que esta possibilidade de tratamento pode gerar benefícios para a satisfação dos pacientes, melhorando a capacidade mastigatória, sem danos para a taxa de sobrevivência dos implantes. Coroas metálicas associadas a implantes do tipo cone Morse demonstraram melhor comportamento biomecânico. De acordo com aanálise de elementos finitos, neste tipo de prótese, um menor comprimento do implante utilizado para modificar a classificação do paciente classe I de Kennedy para classe III não alterou o gradiente de tensões. Há falta de estudos clínicos sobre o uso de implantes distais associados a PPR, considerando a taxa de sobrevivência dos dentes pilares.

Palavras-chave: prótese parcial removível, implantes dentários, biomecânica.

ABSTRACT

The teeth loss causes disharmony in the stomatognathic system, especially when it occurs bilaterally in the posterior mandible. In these cases, free-end removable partial dentures (FERPD) are the most widely used, because it has low cost and do not require any surgical procedures. However, this type of prosthesis have the worst prognosis, since there is an intrusion movement of the FERPD into the ridge and mouth floor that occurs during mastication. To solve this problem, since the early 90's it has been proposed the insertion of an implant in the extreme posterior region of the mandible serving as a stop for the FERPD. However, the literature review does not describe what is the best abutment recommended in this case; nor what is the impact of the treatment proposed for the RPD abutment tooth. The aim of this study was to evaluate the impact of the placement of distal implants to support or retain a FERPD in Kennedy class I patients. First, a systematic review on the subject was performed to evaluate the recent literature. Second, a photoelastic study to evaluate patterns of stress distribution around the implant and abutment tooth to analyze the influence of the implant connection type (internal or external) and the prosthetic implant device (crown or attachment) to support a RPD. Finally, the stress distribution were evaluated around the abutment tooth and in different sizes of implants to support a FERPD associated with a metallic crown, using the Finit Element Analysis. According to the results obtained in the present study, it was concluded that the analyzed treatment benefits the patients' satisfaction and chewing ability, without decreasing the survival rate of implants; metallic crowns associated with Morse taper implants demonstrated better biomechanical behavior. Shorter length of the implant did not alter the patern of stress. There is still a lack of clinical studies on the use of distal implants associated with a FERPD, considering the survival rate of the abutment teeth.

Key words: removable partial dentures, dental implants, biomechanics.

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. Estudos demonstram que mais de 50% das próteses parciais removíveis mandibulares possuem essa classificação (Pellizzer et al., 2010; Vanzeveren et al., 2003a; Vanzeveren et al., 2003b). A perda bilateral de dentes posteriores leva a diminuição da estabilidade muscular da mandíbula, diminuição da eficiência e função mastigatória, perda da dimensão vertical de oclusão e atrição dos dentes anteriores (Budtz-Jörgensen, 1996). O tratamento com próteses parciais removíveis constitui solução não invasiva e de baixo custo para a reabilitação protética de pacientes com arco dentário curto com necessidade funcional e estética de substituição dos dentes posteriores.

No entanto, esse tipo de reabilitação é a que gera maior dificuldade ao paciente em adaptar-se a prótese devido à falta de estabilidade da mesma. Adicionalmente, gera sobrecarga aos dentes pilares, já que a extensão distal destas próteses parciais removíveis não têm suporte dentário, existindo potencial para a transmissão de tensões excessivas ao dente pilar (Ogata, 1992). A diferença da resiliência entre fibromucosa e ligamento periodontal pode gerar aumento da sobrecarga ao pilar direto da prótese, diminuindo sua longevidade. Além disso, os portadores de Prótese Parcial Removível de Extremidade Livre (PPREL) apresentam certo desconforto e insatisfação (Witter et al., 1990; Mendonça et al., 2009). Além disso, com o passar do tempo, o dente que recebe sobrecarga pode, progressivamente, perder inserção óssea.

Esses fatores, somados à indicação de implantes osseointegrados, que apresentam elevados índices de sucesso desde seus primeiros relatos na literatura (Bränemark et al., 1977; Adell et al., 1981), fez com que a utilização de Próteses Parciais Removíveis venha se tornando cada vez menos comum (Christensen, 2006).

A reabilitação de perdas dentárias por meio de próteses parciais fixas implantossuportadas é atualmente realidade clínica inquestionável. Com isso, a sobrevivência dos implantes dentais, nestas condições, tornou-se fato

bem documentado (Attard & Zarb, 2003). Praticamente todos os grandes fabricantes de implantes dentais apresentam acompanhamentos com taxas de sucesso maiores que 90%, muitos por mais de 10 anos (Binon, 2000). No entanto, o custo operacional desse tipo de reabilitação ainda encontra-se inacessível para grande parte da população de baixa renda, principalmente quando envolve próteses mais extensas. Ou pacientes que não possuem condições anatômicas e financeiras para realizar uma reabilitação completa com implantes. Nestes casos, soluções alternativas devem ser propostas, preocupando-se, mesmo com a substituição dos dentes perdidos, uma função mastigatória aceitável (Boretti et al., 1995; Prado et al., 2006; Oliveira et al., 2008; Mendonça et al., 2009; Borges et al., 2011a; Borges et al., 2011b). A avaliação desta função é importante critério de controle de qualidade de tratamentos realizados. Trabalhos recentes demonstram que a utilização de próteses parciais removíveis classe I de Kennedy reduzem a performance mastigatória desses pacientes, quando comparados a outros tipos de tratamento, como o uso de implantes (Mendonça et al., 2009).

As próteses parciais removíveis de extremidade livre (PPREL), pelo fato de não apresentarem suporte dental distal e haver grande diferença entre a resiliência da fibromucosa e movimento de intrusão do dente no alvéolo, são as que apresentam maiores dificuldades de resolução. Desde início dos anos 90, tem sido relatada a colocação de um implante sob a base da extensão distal de prótese parcial removível como alternativa de manter mais estável esse tipo de reabilitação (Hmam et al., 1993), proporcionando solução para as queixas mais comuns dos pacientes contemplados por esse tipo de tratamento. Essa opção de associação da prótese parcial removível com extensão distal a implantes osseointegrados, não só pode atenuar o problema do movimento de base, mas também reduzir o custo do tratamento (Rocha et al., 2003), o que torna a solução mais acessível a parcela da população que realmente precisa (Mitrani et al., 2003; Ohkubo et al., 2008; Grossmann et al., 2009). Estudos laboratoriais já estudam a interação PPR-implante (Verri et al., 2011; Pellizzer. et al., 2010), contudo não diferenciam as junções internas dos implantes.

A maioria dos trabalhos publicados utilizam dispositivos do tipo bola ou cicatrizadores associados ao implante distal (Mitrani et al., 2003; Kuzmanovic et al., 2004; Ohkubo et al., 2008; Grossmann et al., 2009; Liu et

al., 2011, Wismeijer et al., 2011, de Freitas et al., 2012), o que não modifica realmente a classificação da arcada dental, e nem diminui a sobrecarga aos dentes com pouco suporte ósseo, conforme demonstra estudos laboratoriais (Cunha et al., 2011; Verri et al., 2011). Isso acontece devido a resiliência do próprio dispositivo conectado ao implante, que permite pequenos movimentos da prótese em todas as direções, ou, no caso do cicatrizador, por permitir que cargas laterais possam ser aplicadas aos implantes.

Quando associado, o implante osseointegrado essas tensões geradas não causam perda do mesmo, visto que a taxa de sobrevivência desses implantes não diminuem (de Freitas et al., 2012). Porém para o dente pilar direto, essa micromovimentação pode diminuir sua longevidade. Na literatura não há relatos sobre a taxa de sobrevivência dos dentes pilares.

Ressalta-se, ainda, as vantagens econômicas deste trabalho, com custo bem menor ao paciente, uma vez que a prótese parcial removível que o paciente já utiliza pode ser transformada. É uma possibilidade de tratamento temporário (Wismeijer et al., 2011) ou definitivo. Se houver interesse do paciente, nos casos em que existe viabilidade óssea, o mesmo poderá receber próteses implantadas fixas, com a adição de mais um ou dois implantes (Gonçalves et al., 2013; Gonçalves et al., 2014).

Portanto, frente à falta de consenso na avaliação do desfecho, o objetivo deste trabalho é avaliar a influência das PPRs nas estruturas de suporte após a instalação de coroas implantadas distais para modificação da classificação de pacientes classe I em classe III de Kennedy.

CAPÍTULO 1

Karla Zancope, Gizella Moreira Abrão, Frederick Kalil Karam, Flávio Domingues das Neves. Dental implants to convert mandibular Kennedy Class I: a systematic review. Journal of Prosthetic Dentistry.

Abstract

Statement of Problem Authors have reported the placement of a distal implant associated with the removable partial denture (RPD) to make this rehabilitation more stable. This could be an option to solve the intrusion movement of the RPD and also reduce the treatment cost.

Purpose The aim of this systematic review was to evaluate the current literature evidence about the placement of a distal implant associated with a mandibular RPD to improve patient's satisfaction and the clinical performance of the abutment tooth and the distal implant.

Material and Methods This systematic review was conducted by two independent, prosthetic specialists reviewers. Search was performed in PubMed and Cochrane Library databases selected clinical studies with removable partial dentures associated with distal implants published in English up to May 2014. The data extraction form was developed by the authors to collect general information (authors, title, year of publication, aim of the study, level of evidence, number of participants, number of implants used, implant system, implant length and diameter, abutments type, masticatory performance, patients' satisfaction, implant mean bone loss, abutment tooth mean bone loss, prosthetic complications, follow-up period and implant survival rate). The quality of the selected studies was also determined.

Results Initial electronic search identified 231 studies and the manual search identified 15 studies (total of 246 studies). Following the title and abstract reading, full texts of 45 studies were obtained. After removal of duplicates and the articles that did not meet the inclusion criteria, 15 studies had the data extracted. Seven were retrospective studies, 1 was a crossover pilot study, 2 were case series, 2 were paired clinical studies and 3 were case reports, demonstrating that a high number of the selected studies have low methodological quality. Still, high survival rates for RPD associated with dental implants were described.

Conclusions Removable partial denture associated with dental implants to convert a Kennedy class I to class III denture has benefits to patients, improving the satisfaction and masticatory ability, with no damage to implant survival rate. Considering the abutment teeth survival rate, there is still a lack of clinical studies with comparable methodology to define protocols in regards to the use of distal implants associated with RPD. Long-term, prospective clinical trials are still needed to understand which implant abutment increases the abutment teeth survival rate.

Introduction

Free-end removable partial dentures (RPD) is a tooth-mucosa-ssuported denture. Consequently, the masticatory ability decreases, when comparing to fixed rehabilitations.[1] During mastication movements, the resilience difference between the abutment tooth and the posterior ridge mucosa is the major problem on class I RPDs. It results in displacement of the partial denture, also because the loss of occlusal stability and bone resorption. Since the 90s, have been reported that the placement of a distal implant associated with the RPD makes this rehabilitation more stable.[2] This option could solve this intrusion movement[3] of the RPD and also reduce the treatment cost. It may permit that patients with limited financial resources could access this treatment.[4-6]

Clinical[4-15] and *in vitro*[16,17] studies have performed to test the use of distal implants with resilient devices or healing abutments, which do not really convert Kennedy class I or II to a Kennedy class III denture. This situation may reduce the longevity of the abutment teeth, in order of the high stress concentration in this area. There are no published study that report the survival rate of the abutment teeth on RPDs associated with distal implants, even considering two systematic reviews published previously.[18,19]

Furthermore, it is important to emphasize the economic advantages of this rehabilitation protocol. Since the removable partial denture that the patient already uses can be converted, it is a possibility of temporary treatment[9] or permanent. In cases where there is bone viability, it may be planned partial fixed implant prostheses, in future treatment, with the addition of one or two implants.[10]

The aim of this systematic review was to evaluate the current literature evidence about the placement of a distal implant associated with a RPD to improve patient's satisfaction and the clinical performance of the abutment tooth and the distal implant.

Methods

A systematic review was conducted following the PRISMA statement.[20] The review question was formulated using a PICO (Patient Population, Intervention, Comparison, and Outcome) framework:[21]

- Patient/Population: partially edentulous jaw patients.
- Intervention: mandibular bilateral dental implant.
- Comparison: removable partial denture.
- Outcome: clinical performance, patient satisfaction and clinical follow up.

Focused question

Do distal implants when associated with mandibular Kennedy Class I removable partial dentures affect patient satisfaction and the clinical performance of abutment teeth and implants?

Search strategy

A literature search of PubMed and Cochcrane Library databases up to May 2014 was conducted.

The search strategy performed using the following MeSH terms and search terms combination:

"Jaw, Edentulous"[Mesh] OR "Edentulous Jaw" OR "Edentulous Jaws" OR "Jaws, Edentulous";

AND

"Dental Implants"[Mesh] OR "Dental Prosthesis, Implant-Supported"[Mesh] OR "Implants, Dental" OR "Dental Implant" OR "Implant, Dental" OR "Dental Prostheses, Surgical" OR "Dental Prosthesis, Surgical" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Prostheses, Surgical Dental" OR "Prosthesis, Surgical Dental";

AND

"Denture, Partial, Removable"[Mesh] OR “Removable Partial Denture” OR “Denture, Removable Partial” OR “Dentures, Removable Partial” OR “Partial Denture, Removable” OR “Partial Dentures, Removable” OR “Removable Partial Dentures”.

The authors did not use the RCT filter because the absence of this kind of study. A hand-searching was applied additionally, based on the bibliographies of selected articles.

The searching protocol was performed by two prosthetic specialists reviewers (K.Z. and G.M.A.), who independently run the described search and listed the selected abstracts. This list was then compared and a consensus about the final decision regarding the inclusion of articles was reached by discussion of each individual article.

Selection criteria

Prospective controlled clinical studies and clinical studies reporting comparison of patients’ satisfaction and clinical performance (marginal bone changes on abutment teeth and distal implants) of mandibular removable partial denture Kennedy class I associated with distal implants were selected.

Inclusion criteria

English literature was selected if published up to May 2014. All types of human clinical studies with mandibular removable partial dentures Kennedy class I associated with distal implants were included. No restriction on the length of the follow-up period was applied.

Exclusion criteria

Duplicated and published studies that did not meet the inclusion criteria were excluded from this systematic review.

Data collection

The data extraction form was developed by the authors to collect general information (authors, title, year of publication, aim of the study, level of evidence, number of participants, number of implants used, implant system,

implant length and diameter, abutments used, masticatory performance, patients' satisfaction, implant mean bone loss, abutment tooth mean bone loss, prosthetic complications, follow-up period and implant survival rate).

The quality of the selected studies was defined,[22] according to Table 1.

Table 1 - Hierarchy of evidence.

Level of Evidence	Study Design
I	A systematic review of randomized controlled trials
II	A randomized controlled trial
III-1	A pseudo randomized controlled trial (i.e. alternate allocation or some other method)
III-2	A comparative Study with concurrent controls: Non-randomized, experimental trial Cohort study Case-control study Interrupted time series with a control group Systematic reviews of such comparative studies
III-3	A comparative study without concurrent controls: Historical control study Two or more single arm study Interrupted time series without a parallel control group
IV	Case Series

Data analysis

The selected studies did not provide all needed general information and sometimes the information was just in a narrative way. It was impossible to perform a meta-analysis because of lack of some information and heterogeneity of the selected studies.

Results

Initial electronic search identified 231 studies (Figure 1) and the hand-searching identified 15 studies (total of 246 studies). Following the title and abstract reading, full texts for 45 studies were obtained. After removal of

duplicates and the articles that did not met the inclusion criteria (Table 2), 15 studies have the data extracted (Table 3).

Table 2. Articles removed from the systematic review.

Chikunov et al.[23] Minoretti et al.[24] Andreiotelli & Smeekens[25] Zitzmann et al.[26] Chronopoulos et al.[27] Priest[28] Patras & Sykaras[29] Wolfart et al.[30]	Other types of treatment and do not describe the placement of distal implants.
Turkyilmaz[31] Mijiritsky et al.[32] George[33] Giffin[34]	Do not describe specifically a Kennedy class I situation
de Freitas et al.[18] Shahmiri et al.[19] Mijiritsky[35]	Systematic or literature review.
Petricevic et al.[36] Wenz et al.[37] Haltermann et al.[38] Kapur[39] Tanigawa et al.[40]	Do not correlate PRD and dental implants.
Kumar et al.[41]	Describe single implants.
Mahn[42] McAndrew[43] Grossmann[44] Bortolini et al.[45] Fugazzotto et al.[46]	Describe maxillary rehabilitations.
Senna et al.[47] Patras et al.[48]	Do not present the implant survival rate of Kennedy class I associated with distal implants.

Table 3. Summary of included studies.

Authors	Title	Year of publication	Aim	Level of evidence	No. of participants	Total No. of placed implants	Implant system	Implant length (mm)
Gonçalves TMSV, Campos CH, Rodrigues Garcia RCM. [14]	Mastication and jaw motion of partially edentulous patients are affected by different implant-based prostheses	2014	Evaluted the influence of three different prosthetic treatments over the mandibular ability and mandibular movements	III-2	12	Not reported	Titamax, Neodent, Curitiba, Brazil	Not reported
Gonçalves TM, Campos CH, Rodrigues Garcia RC. [49]	Implant retention and support for distal Implant retention and support for distal extension partial removable dental prostheses: satisfaction outcome	2014	Evaluated the use of distal implants to retain and support partial removable dental prostheses and assessed the outcomes with respect to specific aspects of patient satisfaction	III-2	12	Not reported	Titamax, Neodent, Curitiba, Brazil	Not reported
Gonçalves TM, Campos CH, Gonçalves GM, de Moraes M, Rodrigues Garcia RC. [13]	Mastication improvement after partial implant-supported prosthesis use	2013	Evaluated if the increased retention and stability provided by implants would be predictive of masticatory improvements and could affect muscle thickness	III-2	12	48	Titamax; Neodent, Curitiba, Brazil	Not reported
Suzuki Y, Ohkubo C, Kurtz KS. [50]	Clinical application of stress-breaking ball attachment for implant overdenture	2013	Described a clinical report, with the use of SBB attachment for implant-supported overdentures	Case report	1	2	Nobel Replace (Nobel Biocare, Belgium)	Not reported
Mijiritsky E, Lorean A, Mazor Z, Levin L. [10]	Implant Tooth-Supported Removable Partial Denture with at Least 15-Year Long-Term Follow-Up	2013	Described the long-term follow-up of cases treated with implant tooth-supported removable partial denture (ITSRPD) after at least 15 years	III-3	20 (only 6 Kennedy Class I)	12	Zimmer and MIS	10 to 13
Campos CH, Gonçalves TM, Rodrigues Garcia RC. [11]	Implant retainers for free-end removable partial dentures affect mastication and nutrient intake	2013	Measured swallowing threshold parameters and nutrient intake in Kennedy Class I patients	III-2	8	16	Titamax; Neodent, Curitiba, Brazil	6.0, 7.0, 9.0, or 11.0
Wismeijer D, Tawse-Smith A, Payne AG. [9]	Multicentre prospective evaluation of implant-assisted mandibular bilateral distal extension removable partial dentures: patient satisfaction	2013	Compared the levels of patient satisfaction in Kennedy Class I patients before and after the placement of a distal implant	III-2	48	96	SLA (Straumann)	Not reported
El Mekawy NH, El-Negoly SA, Grawish Mel-A, El-Hawary YM. [51]	Intracoronal mandibular Kennedy Class I implant-tooth supported removable partial overdenture: a 2-year multicenter prospective study	2012	Assessed clinical status and radiographic and densitometric periimplant tissue changes as parameters for the success or failure of 40 mandibular implants supporting intracoronal mandibular Kennedy Class I	III-2	20 (19 were evaluated)	40 (38 were evaluated)	BEGO	11.5
Praveen M, Chandra Sekar A, Saxena A, Gautam Kumar A. [52]	A New Approach for Management of Kennedy's Class I Condition Using Dental Implants: A Case Report	2012	Described the fabrication of a mandibular RPD supported by existing anterior teeth and two distal single implants with ball attachments	Case report	1	2	UNITI	13
ELsyad MA & Habib AA. [12]	Implant Supported Versus Implant-Retained Distal Extension Mandibular Partial Overdentures and Residual Ridge Resorption: A 5-Year Retrospective Radiographic Study in Men	2011	Examined posterior mandibular ridge resorption under implant-supported and implant-retained distal extension partial overdentures in men	III-3	34	68	Dyna	Not reported

Grossmann Y, Nissan J, Levin L.[6]	Clinical effectiveness of implant-supported removable partial dentures: a review of the literature and retrospective case evaluation	2009	Described the concept of ISRPDs and the clinical guidelines for placing implants for ISRPDs, and evaluate case series results	III-3	6	10	Zimmer Dental, 3i Implant Innovations, and MIS Implants Technologies	Not reported
Ohkubo C, Kobayashi M, Suzuki Y, Hosoi T.[5]	Effect of implant support on distal-extension removable partial dentures: in vivo assessment	2008	Evaluated implantsupported distal-extension removable partial dentures	III-1	5	10	Branemark TU MK III	8.5–11.5
Kuzmanovic DV, Payne AG, Purton DG.[7]	Distal implants to modify the Kennedy classification of a removable partial denture: a clinical report	2004	Described the fabrication of a mandibular implant-supported RPD with a combination of bilateral single implants	Case report	1	2	ITI	12
Mitrani R, Brudvik JS, Phillips KM.[4]	Posterior implants for distal extension removable prostheses: a retrospective study	2003	Presented a follow-up clinical evaluation consisting of patient satisfaction, radiographic examination, and soft tissue health	IV	10 (6 on mandible)	16 (did not specified witch one were installed in Kennedy Class I patients)	Branemark ITI implants	Not reported
Keltjens HM, Kayser AF, Hertel R, Battistuzzi PG.[15]	Distal extension removable partial dentures supported by implants and residual teeth: considerations and case reports	1993	Described 2 case reports about the association of a RPD and distal implants	IV	2	4	IMZ Implant, Dyna implant	10.0 and 10.5

Implant diameter (mm)	Implant abutment (attachment)	Masticatory performance	Patients' satisfaction	Implant mean bone loss	Abutment teeth mean bone loss	Prosthetic complications	Follow-up period	Implant survival rate
Not reported	Ball abutments and mini-abutments	Subjective evaluation of masticatory function (VAS) improved after implant placement	Not reported	Not reported	Not reported	Not reported	2 months	100% *
Not reported	Ball abutments and mini-abutments	Improved after implant placement (questionnaire)	VAS assessment was significantly greater after the placement of the distal implant	Not reported	Not reported	Not reported	4 months with resilient attachments; 2 months with partial fixed prosthesis	100% *
Not reported	Ball abutments and mini-abutments	Maximum bite force (MBF), food comminution index (FCI) improved after implant placement	Not reported	Not reported	Not reported	Not reported	2 months	100% *
Not reported	SBB attachments	The patient's masticatory function improved by the implant with the SBB attachment.	The patient's satisfaction improved by the implant overdenture with the SBB attachment.	Not reported	Not reported	Not reported	Not reported	100% *
3.7 to 5	Ball attachments	Not reported	The patient's satisfaction Improved after the placement of a distal implant	Ranged between 0 and 2 mm (mean 0.64 ± 0.6 mm)	Not reported	One rest rupture of a clasp assemble around a natural mandibular tooth	24–84 months	100%
6.0, 4.0, or 3.75	Ball abutments	After the placement of distal implants, patients presented better mastication and increased nutrient intake	Not reported	Not reported	Not reported	Not reported	2 months	100% *
4.1	Healing caps; ball attachments after 6 months	Not reported	Participants in the test groups showed significant improvement on the OHIP scores	Not reported	Not reported	Not reported	36 months	100% *
3.75	Healing caps	Not reported	Not reported	0.1 ± 0.01 mm at T0; 0.4 ± 0.24 mm at T24	Not reported	Not reported	24 months	95% (2 failures)
4.3	Ball attachments	Improved masticatory efficiency	The patient was satisfied about the treatment	Not reported	Not reported	Not reported	6 months	100% *
Not reported	G1: healing abutment; G2: ball abutment	Not reported	Not reported	Not reported	Not reported	Not reported	60 months	100% *
Not reported	Locator Attachment (Locator, Zest), O-ring attachment (Zimmer dental), bar and clip	Improvement in mastication (87%)	Increased satisfaction in all patients,	Not reported	Not reported	Not reported	12 – 90 months	100%
3.75	Healing abutment and healing cap	Improvement in mastication	Patient's satisfaction Improved	Not reported	Not reported	Not reported	3 weeks	100% *
4.1	Patrices	Not reported	Not reported	Not reported	Not reported	Not reported	24 months	100% *
Not reported	Group 1: modified healing abutment Group 2: Resilient attachment [OSO, Attachments International; Zaag, Preat; Hader Bar and Clip,	Not reported	Increased patient satisfaction	0.63 mm	Not reported	Pitting Screw loosening Framework fracture Hyperplastic tissue	12–48 months	100%

	Attachments International; or extracoronal resilient attachment (ERA), Sterngold							
3.0 and 3.3	Case 1: Implant provided support: Implant rounded head Case 2: Dyna magnet	Not reported	Increased patient satisfaction	Not reported	Not reported	Repeated relining	24 months	100%

*Considered as 100% survival rate because no implant' loss were described.

Description of studies

Seven were retrospective studies, 1 was a crossover pilot study, 2 were case series, 2 were paired clinical studies and 3 were case reports, demonstrating that a high number of the selected studies have low methodological quality.

Results of analyses

This systematic review analyzed 163 patients and revealed an implant survival rate of 99.13% for mandibular Kennedy Class I associated with a distal implant. The follow-up period was very heterogeneous, ranging from 2 weeks to 120 months. Considering only studies with at least 36 months follow-up,[53] 98 patients received 196 implants, with an implant survival rate of 99.44%.[4,6,9,10,12] The marginal bone loss around implants ranged between 0 and 1.4 mm. The periodontal condition and the abutment tooth survival rate were not described.

The visual analogue scale (VAS) is the most common instrument to evaluate the patients' satisfaction, used in 4 studies,[4,5,9,10] totalizing 65 patients. These studies described an improvement on patients' satisfaction after the placement of the distal implant associated with the RPD. Other studies described an improvement of the patients' satisfaction, but only in a narrative way.[7,15,50-52] The masticatory ability improved after the placement of a distal implant to support a RPD. However, only 3 studies quantified the masticatory performance using food-test[11,13] and questionnaire.[52]

In the selected studies, the described prosthetic complications were: pitting on the surface of the healing abutment, abutment loosening and fractured framework. The implant complications described were: severe inflammation, rest rupture of a clasp assembles around an abutment tooth. Only one study[6] described an abutment tooth loss.

Healing abutments and resilient abutments were described by the selected studies to provide support for the RPD. One study[9] described the

rehabilitation in two stages, using both types of abutments. Others randomized the patients' allocation into two groups.[4,12] Still others,[13,14,52] rehabilitated the patients first with the placement of only the distal implant, and after placed more implants and a partial fixed prosthesis.

Discussion

The use of a distal implant to modify a Kennedy class I arch configuration seems to be a favorable treatment. When this treatment is conducted, the patients' satisfaction and comfort increases. The use of only two implants, with lower cost, can become more accessible.[5,6] The association between retention systems and RPDs can improve patient's satisfaction. A study about the masticatory and nutritional aspects on fixed and removable partial dentures demonstrated that more retentive and stable the prosthesis, more effective is the chewing process.[49] ELsyad et al.,[12] concluded that, for the residual ridge, the better option is to support the RPD with the use of a healing abutment instead of a resilient attachment. However, the best abutment choice must be determined to optimize the clinical results.

Subjective evaluation of masticatory function and patients' satisfaction was quantified, commonly, using a questionnaire based on a visual analogue scale (VAS).[4,5,9,10,14] This method could detect potentially important clinical differences with respect to the masticatory ability.[14] The Optocal food-test was used in 2 studies.[11,13] This is an objective, convenient and reliable method to evaluate mastication.

Nutritional test was described only by one study,[11] and demonstrated no changes on the nutritional behavior on the patients with a distal implant to retain the RPD. The authors concluded that the time was too short and the eating habits did not change after the implants' placement. Therefore, according to the authors, it is still important to provide proper chewing conditions for the patient as well as resources for healthier eating behaviors. More clinical studies with larger follow-up periods are still needed. Several *in vitro* studies[16,17] have demonstrated that the association of a distal implant and a RPD could improve its mechanical behavior. Clinically, healing and resilient abutments are used to support or retain a RPD. However, there is no consensus about the most indicate abutment, a resilient or a rigid abutment.

The implant's type and size evaluated ahd high heterogenity. The length ranged from 6 to 13 mm, and the diameter ranged from 3.3 to 6 mm. Three implants and only one abutment tooth were lost. The mean implant survival rate was 99.13%, considering all studies. The follow-up period was very heterogeneous. However, according to a previous study,[53] the most incidence of implant loss occurred during the first year after prosthesis placement. This incident decrease in the second year of function and it is rare on the third year after prosthesis placement. Considering only studies with at least 36 months follow-up, the implant survival rate was 99.44%, proving that the placement of a distal implant to support/retain a RPD do not affect negatively the implant survival rate. The marginal bone loss around implants ranged between 0 and 1.4 mm. Howeve, the bone loss around abutment teeth was not described, either if there was any damage to the periodontium. Nevertheless, this treatment modality seems to present predictable long-term results.[10]

The most described location for the implant placement was as posterior as possible, to provide maximum stability,[15] but could lead the placement of the implant at the third molar area. This would unnecessary generate a higher stress at the abutment teeth. Three units of mastication (short dental arch) are sufficient for an improvement of the masticatory performance. The authors understand that the placement of the implant at the first or second molar area, considering the bone quality and quantity, already solves the problem. Implant location must be planned, enabling future rehabilitation with implant fixed restoration.[10]

All described prosthetic complications were not related directly to the type of the rehabilitation. One study[5] described an abutment loss, but the study did not described if this loss was associated with resilient abutment, nor the implant site.

Conclusions

It is possible to conclude that removable partial denture associated with dental implant to convert a Kennedy class I to class III denture results in benefits on the patients' satisfaction and masticatory ability and do not prejudice the implant survival rate. There is still a lack of clinical studies with comparable methodology to define protocols about the use of distal implants associated with

RPD, considering the abutment teeth survival rate. Long-term, prospective clinical trials are still needed to understand which implant abutment increases the abutment teeth survival rate.

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Conflicts of interest

The authors declare no conflict of interest.

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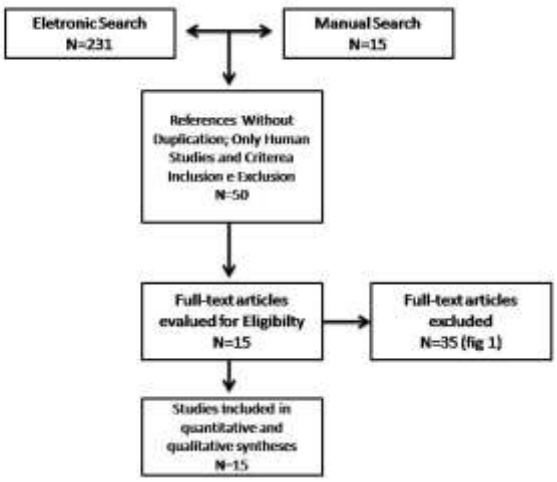

Figure 1 – Flow chart for search strategy.

CAPÍTULO 2

Karla Zancope, João Victor Soares Mendonça Vieira, Carlos José Soares, Flávio Domingues das Neves. Photoelastic stress analysis in removable partial dentures with and without distal implant association. International Journal of Oral and Maxillofacial Implants.

ABSTRACT

Purpose: The aim of this study was to evaluate the patterns of stress distribution aroud teeth and implant to evaluate the influence of implant connection type (internal or external) and device over implants (crown or attachment) supporting a removable partial denture, using photoelastic stress analysis.

Materials and Methods: Five photoelastic models were made and divided in five groups: CT: Kennedy Class I mandible, with first premolars made with acrylic resin, with only the partial removable prostheses (control group); MO: partial removable prostheses supported by Morse taper implants and O'rings; HO: partial removable prostheses supported by external hexagon implants and O'rings; MC: partial removable prostheses supported by Morse taper implants and metallic crowns; and HC: partial removable prostheses supported by external Hexagon implants and metallic crowns. The loading type applied in each model was an axial force (0.8 Kgf) directed over the first molar. Patterns of stress distribution aroud teeth and implant were recorded photographically and evaluated in specific sites.

Results: According to the results obtained, the Group CT had presented the highest fringe order of stress at the apex of the teeth (3.10). Group MO presented 2.35 and 0.6 fringe order of stress at the apex of the teeth and implant, respectively. Group HO, presented 2.00 fringe order of stress at the apex of the teeth, and also 0.6 fringe order of stress at the apex of the implant. Group MC, presented 0.6 fringe order of stress at the apex of the teeth, and 0.0 fringe order of stress at the apex of the implant, the lowest fringe order of stress of all tested groups. Group HC, which presented 2.35 fringe order of stress at the apex of the teeth, and 0.6 fringe order of stress at the apex of the implant.

Conclusions: Based on the stress gradient observed, metallic crowns associated with internal implant connection type to modify the arch classification showed better biomechanical behavior.

Key words: dental implant, removable partial denture, photoelastic stress analysis.

INTRODUCTION

The clinical application of dental implants has shown high rates of success since their first reports in the literature.[1,2] Meanwhile, there are still patients who do not support anatomical or finantial condition to improve their rehabilitation using dental implants. Removable partial dentures still represent an alternative of rehabilitation for partial edentulous patients. Patients with Kennedy class I removable partial denture (RPD) feel discomfort and dissatisfaction[3,4] because tooth and soft tissue (mucosa) respond differently under pressure. The mucosa depresses more than natural teeth under pressure, leading to unfavorable torque on the abutment teeth.[5]

In attempt to solve the difference in resilience between hard and soft tissue, several authors have suggested to install a distal implant in the toothless space, to support the Partial Denture.[6-11] Thus, the use of only two implants can become more accessible for people who needs treatment.[6,8,9] This kind of treatment could be a definitive or a temporary solution; the professional could adapt the removable partil denture that the patient already uses. Later, the patient could install other implants to have an implant partial fixed prostheses.

Clinically, healing and resilient abutments are used to support or retain a RPD. ELsyad et al., concluded that, for the residual ridge, the better option is to support the RPD with the use of a healing abutment instead of a resilient attachment. However, the use of a healing to support a RPD is not recommended by implants' manufacturers. Still, there is no consensus about the most indicate abutment, a resilient or a rigid abutment.

Photoelastic analysis has been largely applied in dentistry to study the stress distribution around dental implants.[12,13] This technique takes advantage of the optical properties of materials that behave in an anisotropic manner under loading, presenting different refraction ratings in the main stress directions.[14]

The aim of the present study was to evaluate the patterns of stress aroud teeth and implant to understand the influence of implant connection type (internal or external) and device (crown or attachment) over implants in the modification of patient's classification Kennedy Class I, using photoelastic stress analysis.

MATERIALS AND METHODS

An epoxi model of a moderately resorbed human edentulous mandible (Kennedy Class I) was molded and a silicon rubber mold were fabricated (Silaex® Química LTDA, São Paulo, Brazil) using an articulated acrylic box. Five photoelastic models were made with a flexible resin (Polipox® Indústria e Comércio LTDA, São Paulo, Brazil). All photoelastic models have the first premolar made with acrylic resin. The models were divided in five groups, according to Table 1. All RPD were planned according to a Kennedy class I removable partial denture situation, and the metallic crown were made with a rest to support the RPD.

The curing of the resin was complete after 24 hours, and the photoelastic model was removed from the mold with smooth movements, preventing residual stress. The photoelastic models were scrubbed with mineral oil, which decreased the refraction and reflection of polarized light at the external surface of the model, thereby improving the ability to visualize the internal stresses.[15,16] The models were taken to a circular polariscope, in the absence of residual stresses resulting from a process called the "edge effect".[14] The optical constant value of the photoelastic resin ($K\sigma = 0.20$) was determined using a calibration process with a compressed disc made with the same photoelastic material.[14] The photoelastic resin used in this study has highly resistant but poor sensitive to large deformations.[17] The load were calibrated allowing better resolution of the fringe orders and a comparative analysis for all evaluated groups.[17] The loading type applied in each model was compressive 0.8 Kgf axial force directed over the first molar, using a load point.

The fringe orders that appear as a series of successive and contiguous bands of different colors represent degrees of birefringence corresponding to the underlying stresses.[18] The axial force was applied, the fringe orders appeared and photos were taken. The fringes were analyzed in detail on a computer monitor with a computer graphic program (Photoshop 9.0, Adobe Systems). The fringes were analyzed in specific points (Fig. 1) according to a previsous study,[18] which used a definited color scale (Fig. 2) to classify the fringes.[18]

RESULTS

Figures 3 to 7 showed the isochromatic fringe patterns and orders around the teeth and implants on the loaded side. The fringe orders of each point was described on Table 1.

According to the results obtained, the Group CT (control) presented the larger stress at the apex of the teeth (Fig. 3). This group generated 3.10 fringe order of stress at the apex of the teeth.

Group MO presented 2.35 fringe order of stress at the apex of the teeth, and 0.6 fringe order of stress at the apex of the implant (Fig. 4). This group presented simillar results than group HO, which presented 2.00 fringe order of stress at the apex of the teeth, and also 0.6 fringe order of stress at the apex of the implant (Fig. 5).

The most satisfactory results were presented by Group MC, presented 0.6 fringe order of stress at the apex of the teeth, and 0.0 fringe order of stress at the apex of the implant (Fig. 6). This group presented better results than group HC, which had 2.35 fringe order of stress at the apex of the teeth, and also 0.6 fringe order of stress at the apex of the implant (Fig. 7).

DISCUSSION

Data from this study revealed differences on stress distribution around teeth and implants. Results favored the use of internal connections associated with metallic crowns (group MC). The groups that used an external connection presented high stress concentration at the apex of teeth and implant, irrespective of the abutment type.

The use of only two implants decrease the treatment cost, mainly if the patient still use a removable partial denture. However, the installation of two distal implants with retention system do not actually modify the classification of dental arches. The overload under the teeth and bone support do not reduce.[19,20] The present study demontrated that the modification of the class arch reduced the tendency of displacement of the abutment tooth. The association with retention systems maybe only improve patients' satisfaction with the removable partial denture. To use the retention system, the placement direction of the implant should be as parallel as possible. When is performed a metallic crown the clinician must adapt the removable partial denture to add a

clasp to rest at the metallic crown. This situation modify the arch classification, which may reduce the stress around the teeth.

The implant connection type may influence the stress distribution around implants. The internal implant connection type at the level of the marginal bone substantially decreased peak bone stresses.[21] The evaluation of the stress on the prosthesis/implant/bone/teeth complex in this critical situation contribute to understand the impact of the choice of the abutment connection design. The use of internal implant connection type may improve the treatment success.

The models used in this study simplify clinical conditions. However, the method used in this study was correctly indicated given the complex geometry and loading of the models.[13] The photoelastic technique has advantages over other methods.[14] However, do not exclude the importance to perform this study using other biomechanical test, such as Finit Element Analysis.

A clinical study is recommended to validate this results. The use of only two implants reduce the cost for this type of patients, becoming more accessible for people who needs treatment,[6,8,9] improving the patients' masticatory efficiency.

CONCLUSION

Within the limitations of this study, based on the stress gradient observed in this study, internal connections associated with metallic crowns to modify the arch classification demonstrated better biomechanical behavior. The external connection presented high stress concentration at the apex of teeth and implant, irrespective of the abutment type.

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FIGURES

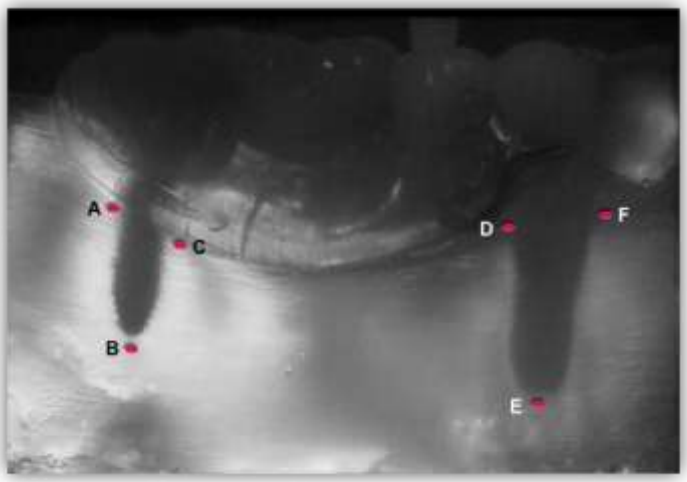
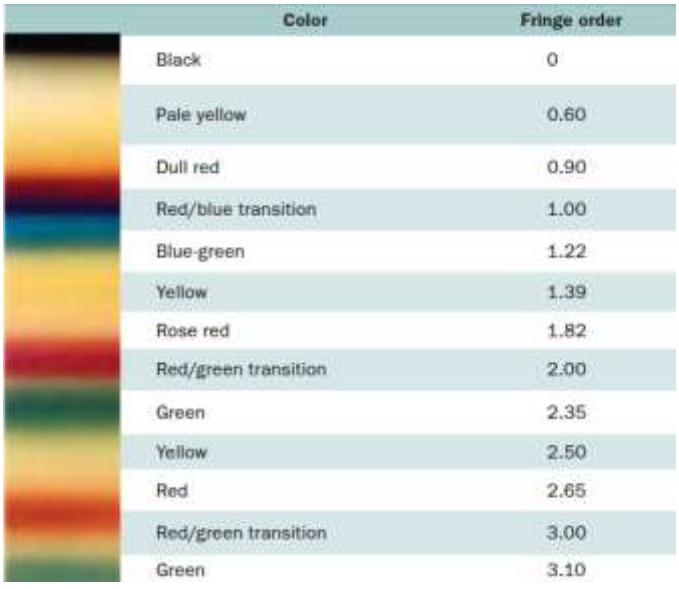


Figure 2 - Fringe orders analysed points.



Color	Fringe order
Black	0
Pale yellow	0.60
Dull red	0.90
Red/blue transition	1.00
Blue-green	1.22
Yellow	1.39
Rose red	1.82
Red/green transition	2.00
Green	2.35
Yellow	2.50
Red	2.65
Red/green transition	3.00
Green	3.10

Figure 3 - Isochromatic Fringe Characteristics.

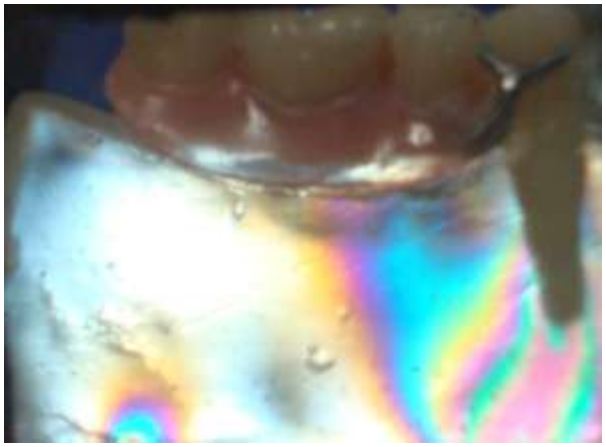


Figure 4 - Stresses produced by the prostheses on Group A.

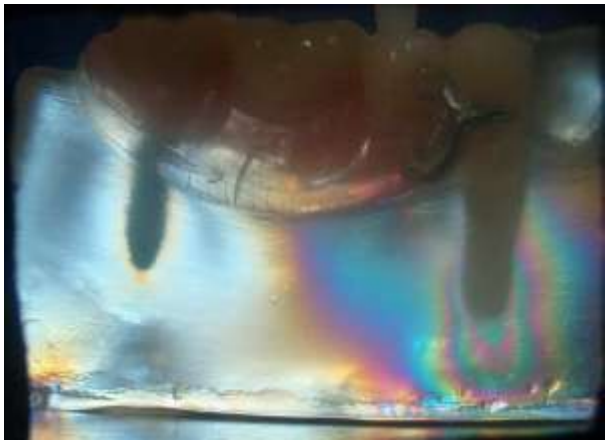


Figure 5 - Stresses produced by the prostheses on Group B.

Figure 6 - Stresses produced by the prostheses on Group C.

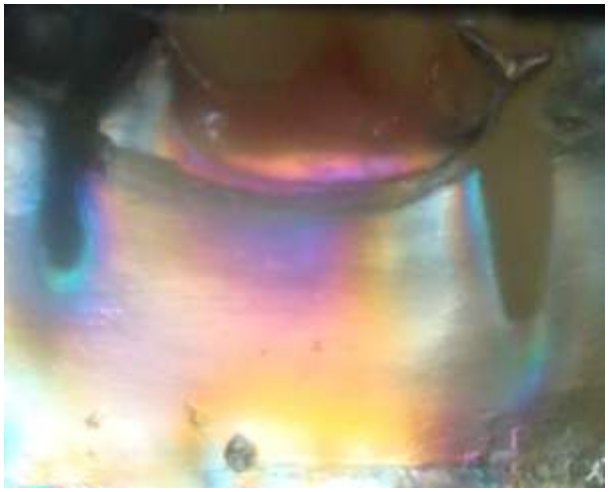


Figure 7 - Stresses produced by the prostheses on Group D.

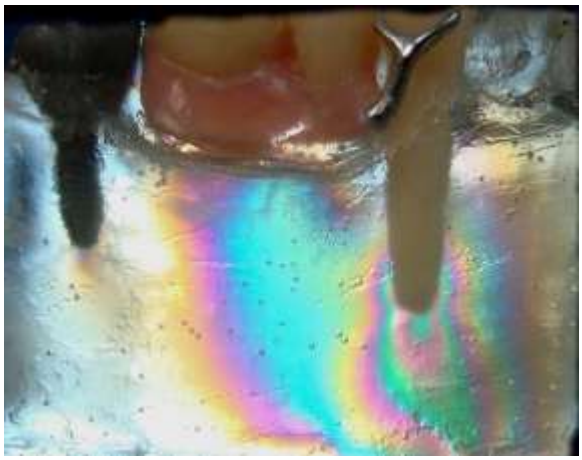


Figure 8 - Stresses produced by the prostheses on Group E.

Table 1 – Tested groups.

Group CT	Kennedy Class I mandible, with first premolars made with acrylic resin, with only the partial removable prostheses (control group)
Group MO	Kennedy Class I mandible, with first premolars made with acrylic resin, with the partial removable prostheses supported by Titamax CM EX implants (3.75mmx9.0mm, Neodent, Curitiba, Brazil), CM Mini Ball Atachments (1.5mm, Neodent, Curitiba, Brazil) and O'rings with cylinder for Mini Ball Attachments (Neodent)
Group HO	Kennedy Class I mandible, with first premolars made with acrylic resin, with the partial removable prostheses

	supported by Titamax TI EX implants (3.75mmx9.0mm, Neodent), Mini Ball Atachments (4.1x2mm, Neodent) and O'rings with cylinder for Mini Ball Attachments (Neodent)
Group MC	Kennedy Class I mandible, with first premolars made with acrylic resin, with the partial removable prostheses supported by Titamax CM EX implants (3.75mmx9.0mm, Neodent), CM Universal Posts (4.5x4.0x0.8mm, Neodent) and Castable Universal Post Cylinders (4.5x4.0mm, Neodent)
Group HC	Kennedy Class I mandible, with first premolars made with acrylic resin, with the partial removable prostheses supported by Titamax TI EX implants (3.75mmx9.0mm), Castable anti-rotational UCLA (4.1mm, Neodent) and Hex screws (4.1mm, Neodent)

Table 2 - Fringe orders of all groups.

	Point A	Point B	Point C	Point D	Point E	Point F
Group A	N.A.	N.A.	N.A.	1.22	3.10	1.22
Group B	0	0.6	0	0.6	2.35	0.6
Group C	0	0.6	0.6	0	2.00	1.22
Group D	1.00	1.00	1.00	0.6	0.6	0
Group E	0	0.6	0	0.9	3.1	0.9

* N.A. = Not aplicable.

CAPÍTULO 3

Karla Zancope, Gizela Moreira Abrão, Aline Aredes Bicalho, Carlos José Soares, Flávio Domingues das Neves. Stress distribution in Kennedy Class I mandibular removable partial denture associated with distal implants: a Finite Element Analysis. Brazilian Oral Research.

Abstract

Purpose: Removable partial dentures (RPD) still figure as a prosthetic solution for several patients, especially for the preservation of tooth structure, reversibility and low cost. However, mandibular Kennedy Class I patients have worse prognosis with this apparatus. Thus, the aim of this study was to qualitatively compare, through experimental two-dimensional Finite Element Analysis (FEA), the stress distribution around the abutment tooth and posterior ridge of conventional free-end removable partial dentures (FERPD) and those associated with different types of dental implants supporting metallic crown.

Materials and Methods: For the analysis, four hemi-mandibles models with 1st and 2nd premolars were obtained: Group CT- control with conventional FERPD; Group - RPD associated with external hexagonal implant (3.75 x 9.0 mm); Group CC - RPD associated with Morse taper implant (3.75 x 9.0 mm); and Group SC - RPD associated with wide and short implant (4 x 5 mm). The models were loaded in the Finite Element software with vertical pressure of 10N on each cusp tip, totalizing 60N per model.

Results: Group CT exhibited higher stress concentration on the abutment tooth. A reduction of stress was observed on abutment tooth for all models with RPD associated with implants, irrespective of the implant type.

Conclusion: The placement of a distal implant to modify the patient's arch classification is a good alternative to improve the internal pattern of stress, in order to reduce the limitations of this type of prosthesis. This treatment alternative can reduce costs for patients and probably improve the function and viability of RPDs.

Key words: biomechanics; dental stress analysis; finite element analysis; implants; removable partial denture.

Introduction

To rehabilitate partial edentulous patients several types of treatment could be proposed, such as removable partial denture, fixed partial denture and dental implant fixed prosthesis. The decision on the oral rehabilitation of patients is, sometimes, guided by cost. The best functional results are found

with implant-based prosthesis, because it brings longevity and comfort. However, this type of prosthesis still represents high costs for some patients.

Removable partial dentures (RPD) represent an acceptable and economic treatment modality for patients with reduced dentition.[1,2] It can preserve teeth, restoring vertical dimension of occlusion and rehabilitating prosthetic spaces at low cost.[3] Over 50% of RPDs are mandibular Kennedy Class I, what means, free-end bilateral edentulous.[4] This type of RPD has the worse prognosis,[5] and patients report them as uncomfortable, sometimes preferring not to use this device. The prognosis of the RPDs abutment tooth is unfavorable. A study[6] observed that 11.4% of the abutment tooth of Class I RPDs was lost within 10 years, assessing the complications and failures in free-end removable partial dentures (FERPDs).

In order to protect the abutment tooth of RPDs for a relative low cost and to increase support and retention, the possibility of placing an implant as distally as possible should be taken into consideration.[7] The association of RPDs with implants is suggested to improve life quality,[6] patients' satisfaction with the prosthesis,[8-10] prosthetic stability and occlusion.[11] Several studies reported the success rate of RPD combined with implants,[9,11,12] but the influence of different junctions and ultra short implants on the stress reduction around abutment tooth was not discussed yet. The focus of other studies was the stress transmitted to the implant,[4,13,14] not to the abutment tooth. On this way, Finite Element Analysis (FEA) can be a viable alternative to help understanding the stress pattern under this condition.

FEA is a technique for obtaining solutions to complex mechanical problems by dividing the problem domain into a collection of much smaller and simpler domains (elements) in which field variables can be interpolated with shape functions.[14] The process of creating the mesh, elements, their respective nodes, and defining boundary conditions is referred to as "discretization" of the problem domain. The FEA is extremely useful to indicate biomechanical aspects of biomaterials and tissues, as well as to reduce the number of laboratory tests required and inherent costs. This analysis allows the determination of stresses resulting from external forces, pressure, thermal changes, and other factors.

Thus, the aim of this study was to compare qualitatively through experimental two-dimensional FEA, the stress distribution around the abutment tooth of conventional FERPD and those associated with different types of dental implants supporting metallic crown. The null hypothesis of this study was that there is no difference in the stress pattern of the RPDs abutment tooth and posterior ridge when a distal implant is installed.

Materials and methods

The Finit Element Analysis was performed at CPBio (School of Dentisty, Federal University of Uberlândia, Uberlândia, Brazil). Four two-dimensional models were generated under sagittal aspect, simulating partially edentulous hemi-mandibles, presenting only first and second left lower premolars. The number of remaining teeth, the length of the free-end edge, the characteristic of periodontal support and protection, biological distances (alveolar crest, cementum/ enamel tissue attachment), mandibular bone height, the thickness of the metallic structure of CoCr and the number of artificial teeth were all based on current literature.[14]

The models were based on a previous design,[15] which was transported to Image J program (public domain, Java-based image processing and analysis software, NIH, Bethesda, MD, USA), where the X and Y coordinates of the structures were collected. These coordinates were then transferred to the finite element software where the stress analysis was performed by MSC.Mentat software (MSC Software; Santa Ana, CA, USA) as the pre and post-processor and MSC.Marc software (MSC Software; Santa Ana, CA, USA) as the solver. The implants and prosthetic components design were provided by the manufacturer (Neodent, Curitiba, PR, Brazil). The groups are described on Table 1.

Table 1- Characteristics of the models.

Group CT	Presence of 1st and 2nd premolars, with conventional free-end RPD.
Group HC	Presence of 1st and 2nd premolars, with RPD, External Hexagonal (EH) implant (3.75 x 9.0 mm), solid universal

	abutment (4.5 x 6.0 x 1.0 mm) and metallic crown.
Group CC	Presence of 1st and 2nd premolars, with RPD, Morse Taper (MT) implant (3.75 x 9.0 mm), solid CM universal abutment (4.5 x 6.0 x 3.5 mm) and metallic crown.
Group SC	Presence of 1st and 2nd premolars, with RPD, ultra-short Morse Taper (WS) implant (4 x 5 mm), WS universal abutment (4.5 x 6.0 x 0.8 mm) and metallic crown.

All models were considered homogeneous, isotropic, and linearly elastic. The models were assumed in a plane stress condition. In an isotropic material, the properties are the same in all directions and therefore there are only two independent constants of the material. The materials mechanical properties are described on Table 2.

Table 2. Mechanical properties assigned to materials.

STRUTURE	YOUNG'S MODULUS (GPA)	POISSON'S RATIO (V)
Enamel[16]	41	0.30
Dentin[16]	18.6	0.31
Trabecular bone[16]	1.37	0.30
Cortical bone[16]	13.7	0.30
Periodontal ligament[16]	0.0689	0.45
Co-Cr[17]	185.0	0.35
Titanium[18]	103.4	0.35
Acrylic Resin[19]	8.30	0.28
Fibromucosa[20]	0.68	0.45
Metal Crown[17]	185.0	0.35

In MSC.Marc software, the mesh was created and refined manually in quadratic elements. Then, the boundary conditions were determined. The cortical bone at the model base was fixed in the *x* and *y* axis, to restrict movement of the model.

Vertical loading of 10N was applied and distributed on 18 nodes at each cusp (previously determined), totalizing 60N. The models were processed and the results displayed in von Mises stress criterion. The models were set to the same scale to adequate interpretation and comparison between the stress maps. Some structures of interest were individualized for improved viewing. The areas of greatest interest to this study were: abutment tooth and posterior ridge.

To analyze the stress concentration at the posterior region of the abutment tooth, 23 nodes were selected and the nodal stress concentration on abutment tooth was ploted.

Results

All models demonstrated high stress concentration on the second premolar abutment tooth (2nd premolar) according to Figure 1 (A, B, C, D). The distal implant reduced the stress level in the abutment tooth. Model A presented higher stress concentration on the abutment tooth. All other models demonstrated a high stress concentration in the support area between abutment tooth and RPD (distal rest).

The surrounding structures at the distal region of the abutment tooth exhibited the higher stress levels. The highest value was found in cortical and trabecular bone (Fig. 2). Stress values from 23 nodes of this region were plotted, and some homogeneity in the stress distribution was observed for all models with implants associated (Fig. 3). High stress concentration was detected in Group CT (Fig. 4).

In trabecular bone, increased stress concentration was observed at the apex of the implant and abutment tooth and in the region below the base of the RPD. With the implant placement, stress concentration decreased in the region below the RPD for all implant models (Fig. 5).

Discussion

The stress pattern of the RPD abutment tooth has changed when a distal implant was placed (Figure 4). A recent review[21] has found implants associated to RPDs survival rates up to 95.5%. However, the survival rate of abutment tooth was not the focus of studies that analyze this kind of treatment.[4,13,14] The preservation of the abutment tooth on RPDs should also be considered to

assure clinical indication for this treatment. According to the obtained results in this study, the placement of distal implants to support metallic crowns associated to RPD decreased stress values in the adjacent structures of the abutment tooth.

A clinical study concluded that RPD associated with the placement of distal implants and ball retainers increased the masticatory efficiency and absorption of nutrients in partially edentulous patients.[22] However, this study did not used a rigid retainer as described by ELsyad et al.,[12] which conducted a retrospective radiographic study in men, evaluating the association of RPDs with implants, using healing abutments or resilient ball attachments. The authors showed lower bone resorption when the prosthesis were supported by healing abutments, even after 5 years of follow-up. These findings may be related to the presence of space between the components of the resilient ball attachment,[12] which may permit free vertical rotation of the prosthesis during function with concentration of diverse forces on the residual ridge areas. This unrestricted vertical and presumably horizontal movement could result in most of the masticatory load being transferred directly to the posterior edentulous ridge, with minimal stress transmitted to the implants. Increased bone loading as a result of this resilient support could then contribute to increased ridge resorption since it interferes with blood circulation in the mucosa and alveolar bone, as well as loading bone unfavorably.[12]

One alternative is the transformation of Kennedy Class I to Kennedy Class III situation, associating the distal implant to support a metallic crown, altering the clinical condition of tooth-mucosa-supported to a tooth-implant-supported condition. This alternative could be a temporary solution for the patient, which could plan to receive an implant-supported fixed restoration.[23]

Patient satisfaction and improvement of the life quality are key factors in prosthetic rehabilitation. Even though the association of RPDs to implants should not be the first option, we must take it into account in cases where obstacles can prevent fixed treatments on teeth or implants. Also, a multicenter prospective *in vivo* study[9] lasting 2 years was conducted to ascertain the health of the tissues of 40 mandibular implants that supported Kennedy Class I RPDs through clinical, radiographic and parametric densitometry. A success rate of 95% of the implants was shown after 24 months and this treatment modality can

be considered a successful alternative for rehabilitation of mandibular bilateral posterior edentulous patients. The success rates of implants seem to be well documented, but the survival of RPD abutment tooth is not always reported in the literature.

The insertion of the distal rest seat reduces the stress levels in the cortical and trabecular bone.[13] Thus, this rest localization was used in the present study since it was not possible to perform in two-dimensional FEA model exactly as the clinical indication for class I RPD: a mesial rest and a T-clasp.

The external hexagonal implant type was used because of its well-established reputation and longevity of clinical studies that translate their success.[24] Its reduced clinical cost compared to Morse junction should be taken into account for this type of rehabilitation. Morse taper implant type was used because its junction has shown less screw loosening and greater strength.[25] Both designs of implants used in this study were provided by the manufacturer in the same length and diameter (3.75 mm X 9.0 mm). The WS wide and short Morse taper implant type was included because free end posterior region is generally associated with reduced bone height or not adequate position of the mandibular canal.[26] In these situations, the ultra-short implant could be used with high survival rates.[26-28] According to our study, the use of ultra-shorts implants did not increased the stress levels on the abutment tooth or on posterior ridge.

Conducting a clinical study without prior laboratory tests to check the real biomechanical behavior of a new treatment approach would be costly, time consuming and also involve patients in important clinical failures. Thus, laboratory investigations should precede clinical evaluations. The rapid advance and development of technologies in dentistry has made modeling using finite elements a very important tool in the study of new techniques and materials. The two-dimensional method was chosen because it can represent many such complex structures, requiring less computational processing than a 3D model, without reducing the reliability of the results. Further clinical studies need to be performed.

Conclusion

According to the results obtained in this study and the limitations of this methodology, it can be concluded that the association of RPD with dental implants restored with metallic crown demonstrated less stress in abutment tooth. Different connection types (External Hexagonal and Morse Taper) exhibited no difference in the stress on abutment tooth, as well as the use of ultra-short implants.

Acknowledgments

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Figure captions

Figure 1 – Stress maps: Model A (control), Model B (EH), Model C (MT), Model D (WS).

Figure 2 – Stress maps of the surrounding structures at abutment tooth: periodontal ligament, cortical bone, and trabecular bone. Group CT (A), Group HC (B), Group CC (C) and Group SC (D).

Figure 3 – Nodal stress concentration on abutment tooth.

Figure 4 – Von Mises stress at respective nodes.

Figure 5 – Trabecular and cortical bone von Mises stress maps: Group CT (A), Group HC (B), Group CC (C) and Group SC (D).

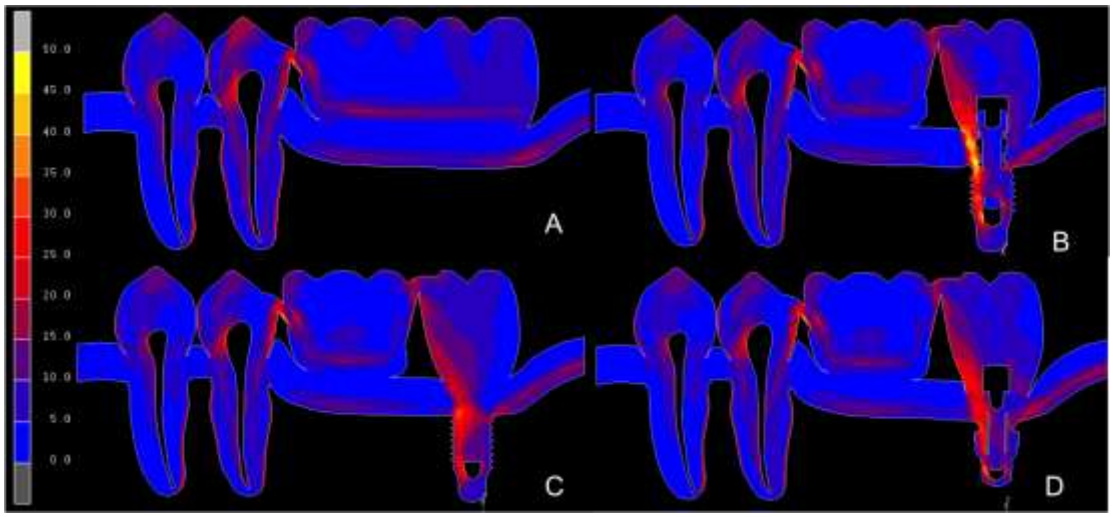


Figure 1. Stress maps: Group CT (A), Group HC (B), Group CC (C) and Group SC (D).

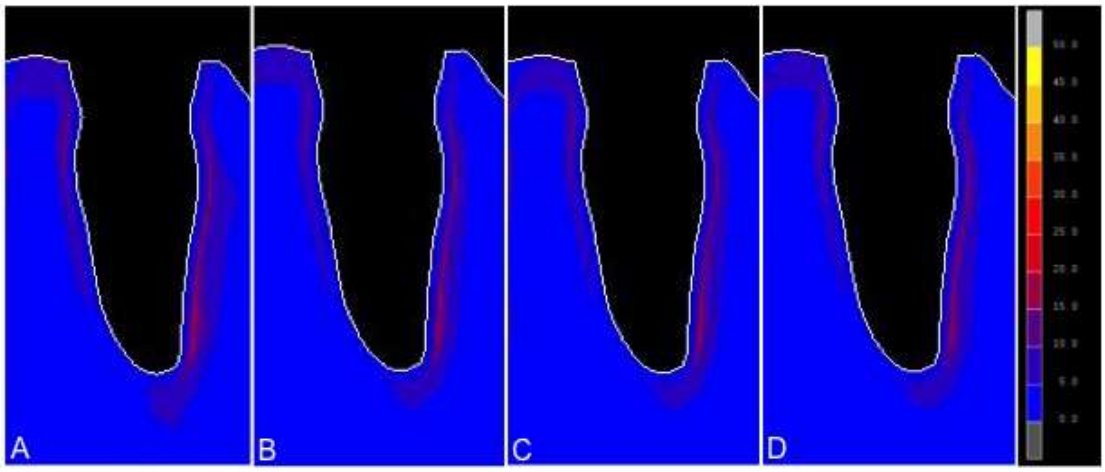
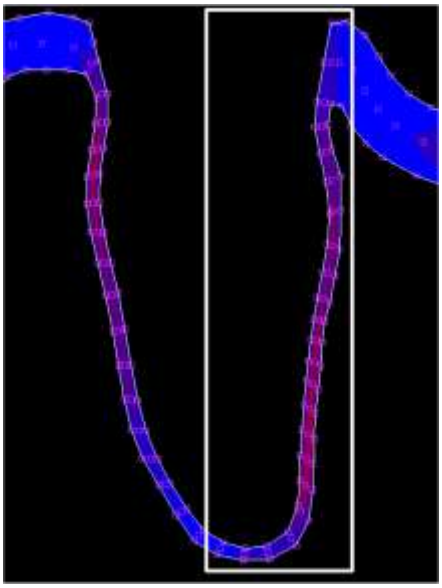


Figure 2. Stress maps of the surrounding structures at abutment tooth: periodontal ligament, cortical bone, and trabecular bone. Group CT (A), Group HC (B), Group CC (C) and Group SC (D).



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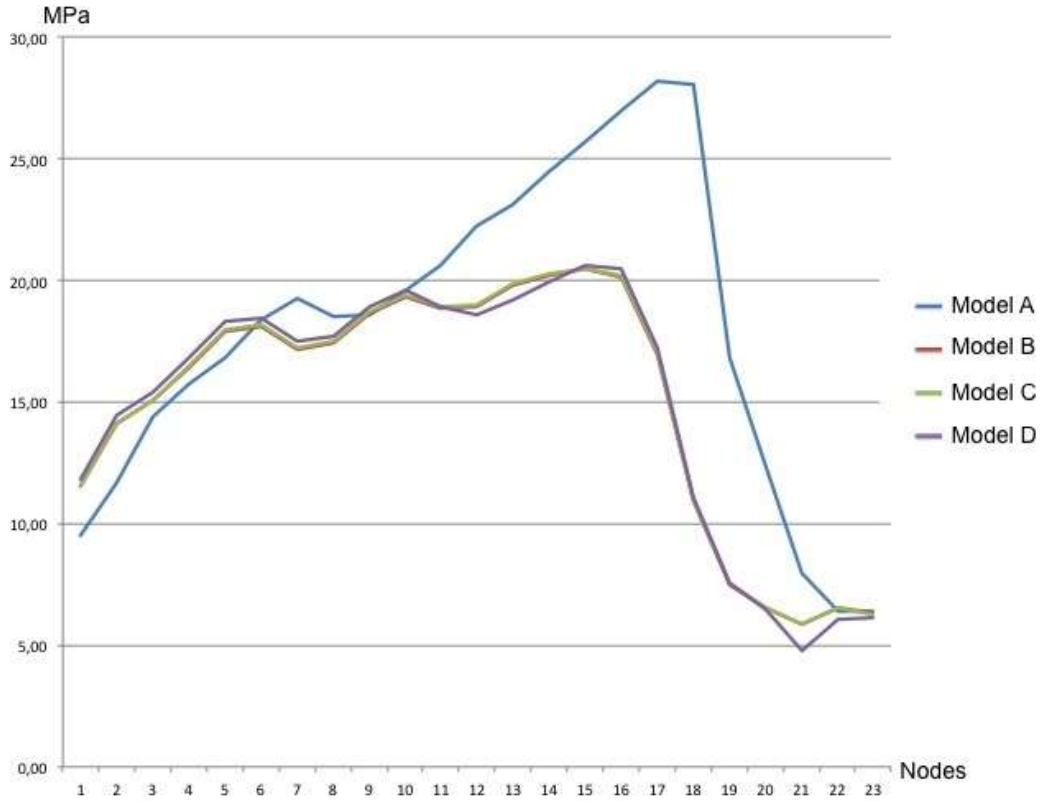

Figure 4. Von Mises stress at respective nodes.

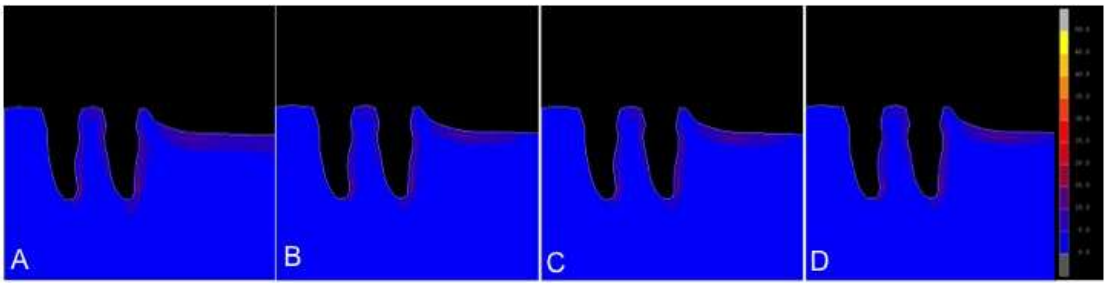

Figure 5. Trabecular and cortical bone von Mises stress maps: Group CT (A), Group HC (B), Group CC (C) and Group SC (D).

3- CONSIDERAÇÕES FINAIS

Diante dos resultados obtidos e apresentados nos capítulos desta tese, pôde-se entender melhor de que maneira ocorre a distribuiçãoo de tensões nos tecidos de suporte do dente pilar de uma PPREL quando associada a um implante distal.

Embora na literatura nao haja um consenso sobre o tipo de dispositivo a ser utilizado sobre o implante, nota-se que a utilização de dispositivos resilientes nao é a melhor opção. Esse tipo de dispositivo permite que ocorra movimentos de intrusão no momento da mastigação, podendo transmitir ao dente pilar uma carga excessiva. Essa estiímulo de compressão no osso, a longo prazo, pode determinar a perda da insersão óssea do dente pilar de PPREL, determinando uma menor longevidade ao tratamento proposto.

A utilização do cicatrizador como apoio para a PPREL, embora bastante descrito pela literatura, nao foi testado no presente estudo pois não é a indicação de uso do dispositivo. Desta forma, poderia ser causado algum dano a integridade mecânica do implante, além de ocorrer a possibilidade de complicações protéticas irreversíveis.

Com isso, somente a transformação da clssificação do arco do paciente de classe I para classe III de Kennedy pode atenuar as forças que são transmitidas ao dente pilar. A instalação de uma coroa metálica distal para servir de apoio a PPR transformaria a reabilitação em dento-implanto-suportada, distribuindo melhor as tensões e protegendo o dente pilar direto da PPR.

Nenhum estudo descreve a taxa de sobrevivência do dente pilar direto da PPR. Mas com os resultados do presente estudo, a instalação de uma coroa metálica, bilateralmente, para transformar um arco classe I para classe III de Kennedy, prevê um bom prognóstico ao tramento proposto.

Desta forma, um estudo clínico prospectivo está em andamento e obedecerá as regras do CONSORT (Consolidated Standards of Reporting Trials). O CONSORT é um conjunto de diretrizes (check list) que devem ser seguidas nos estudos clínicos, para padronização e confiabilidade dos dados obtidos (Moher et al., 2001).

Para o cálculo do tamanho da amostra (n) utilizou-se o programa Sigmaplot 12.0 para Windows (Systat Software Inc, USA). Considerando a expectativa da diferença média igual a 0,70, a expectativa do desvio padrão igual a 0,80, o poder do estudo (1-β) igual a 0,80 e o erro tipo I (α) igual a 0,05 (Paolantonio et al, 2008), estimou-se um tamanho amostral mínimo de 13 unidades. Entretanto, como são inúmeras variáveis em um estudo clínico desta magnitude, serão necessários mais pacientes para evitar viés no estudo.

O grupo, portanto, será constituído por indivíduos portadores de prótese total superior e prótese parcial inferior satisfatória. Após a autorização de cada paciente, expressa em termo de consentimento livre e esclarecido, as próteses estão sendo avaliadas quanto a sua qualidade. Será usado um protocolo para avaliação clínica dessas próteses.

Os critérios para avaliação física-funcionais são:

1. Critérios físicos: extensão e espessura das próteses e alinhamento, disposição e desgaste dos dentes.
2. Critérios funcionais: dimensão vertical, estética externa ou facial do paciente e estética das próteses, fonética do paciente, oclusão, retenção e estabilidade das próteses.

As próteses com qualidade satisfatórias serão apenas transformadas para a situação proposta, enquanto que as próteses insatisfatórias receberão reparos ou trocas, de acordo com a necessidade.

Os pacientes serão avaliados sistêmica, clinica e radiograficamente quanto a possibilidade da instalação dos implantes, que serão cedidos pela empresa Neodent, assim como os componentes protéticos.

O estudo clínico conta com as seguintes metodologias:

1- Avaliar, por meio da Colorimetria, a performance mastigatória de pacientes classe I de Kennedy, antes e após a instalação de dois implantes distais que modificarão a classificação do arco dentário para classe III de Kennedy;

2- Comparar, a performance mastigatória após a instalação de dois implantes distais que modificarão a classificação do arco dentário para classe III de Kennedy com a performance mastigatória de pacientes completamente dentados;

3- Avaliar, por meio de exames clínicos e radiográficos, a sobrevida de dentes pilares diretos de prótese parcial removível e dos referidos implantes na situação proposta;

4- Descrever as principais complicações protéticas;

5- Avaliar a condição nutricional por meio da Mini-Avaliação nutricional (questionário MAN) e exame hematológico;

6-Avaliar a satisfação com as próteses antes e após a instalação dos implantes distais, e;

7-Avaliar a qualidade de vida relacionada a saúde oral (questionário OHIP-14Br).

4- CONCLUSÕES

De acordo com os resultados obtidos nos estudos laboratoriais e as informações coletadas por meio da revisão sistemática, pode-se concluir que:

1- A possibilidade de tratamento analisada (implantes dentários associados a PPR classe I de Kennedy para transformar em classe III de Kennedy) traz benefícios para a satisfação dos pacientes e capacidade mastigatória, sem danos para a taxa de sobrevivência dos implantes nem para as estruturas de suporte após a instalação de coroas implantadas distais para modificação da classificação de pacientes classe I em classe III de Kennedy;

2- Com base no gradiente de tensões observado nos modelos fotoelásticos, implantes de conexões internas associadas com coroas metálicas para modificar a classificação do arco demonstrou melhor comportamento biomecânico. Os implantes de conexão externa apresentaram alta concentração de tensões no ápide dos dentes pilares e implantes, independentemente do tipo de pilar;

3- Menor comprimento do implante utilizado para modificar a classificação do paciente classe I de Kennedy para classe III não alterou o gradiente de tensões, de acodo com a análise de elementos finitos com modelos 2D, e;

4- Ainda há falta de estudos clínicos sobre o uso de implantes distais associados a PPR, que comprove o benefífio à taxa de sobrevivência dos dentes pilares.

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