UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ODONTOLOGIA DE PIRACICABA

ALFONSO SÁNCHEZ AYALA

EFEITO DA ALTERAÇÃO DO SUPORTE OCLUSAL NA MASTIGAÇÃO DE PORTADORES DE PRÓTESES REMOVÍVEIS

Tese de Doutorado apresentada à Faculdade de Odontologia de Piracicaba da UNICAMP para obtenção do título de Doutor em Clínica Odontológica, na Área de Prótese Dental.

Orientadora: Profa. Dra. Renata Cunha Matheus Rodrigues Garcia

Este exemplar corresponde à versão final da Tese defendida pelo aluno Alfonso Sánchez Ayala, e orientada pela Prof[a.] Dr[a.] Renata Cunha Matheus Rodrigues Garcia.

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Banca examinadora:
Renata Cunha Matheus Rodrigues Garcia [Orientador]
Fernanda Faot
Maria Beatriz Duarte Gavião
Cinthia Pereira Machado Tabchoury
Adriana Silva de Carvalho

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Profa. Dra. FERNANDA FAOT

Profa. Dra. MARIA BEATRIZ DUARTE GAVIÃO

Profa. Dra. CINTHIA PEREIRA MACHADO TABCHOURY

Profa. Dra. ADRIANA SILVA DE CARVALHO

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Então, elevaremos o plano do nosso esforço,
procurando que a atividade realizada se converta em encontro com o Senhor,
e sirva de base aos outros, aos que hão de seguir o nosso caminho...”

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RESUMO

Evidências científicas que determinem a influência do suporte oclusal (SO) reabilitado na função mastigatória são insuficientes. A proposta deste estudo foi avaliar a influência do SO na função mastigatória de portadores de próteses removíveis. Vinte e três indivíduos edêntulos (idade média=55.2 ± 8.4 anos) foram reabilitados com prótese total superior e parcial removível inferior (PPR). Cinco condições de SO foram determinadas através do desgaste dos dentes das PPRs: SO completo *(L1–*condição controle*)*, SO até 1° molar *(L2)*, até 2° pré-molar *(L3)*, até 1° pré-molar *(L4)*, e ausência de suporte oclusal *(L5)*. Performance e eficiência mastigatórias foram avaliadas por meio da mastigação de cubos de Optocal de 5.6 mm de aresta utilizando 20 ciclos mastigatórios. A performance mastigatória foi determinada pelo tamanho mediano de partícula (X_{50}) utilizando o método das peneiras (0,5–5,6 mm). A eficiência mastigatória foi determinada pela porcentagem do material que atravessou as peneiras de 5,6, 4, 2,8 e 2 mm. O número de ciclos mastigatórios realizados por minuto foi considerado como taxa mastigatória. A chance de seleção e função de fratura foram avaliadas realizando-se um ciclo mastigatório simultaneamente para tamanhos de 8, 4,8 e 2,4 mm dos cubos de Optocal. O padrão de ciclo mastigatório foi qualitativamente analisado por meio das trajetórias, e quantitativamente examinado por meio das aberturas e áreas máximas registradas utilizando cinesiografia. Na primeira parte do trabalho, o impacto súbito de cada condição de SO na função mastigatória foi avaliado. Em um segundo momento, a adaptação a cada condição de SO foi semanalmente analisada. Assim, as variáveis foram mensuradas imediatamente após a obtenção de cada condição, e após uma semana de uso das próteses nestas mesmas condições. Foram aplicados os testes de *ANOVA* para medidas repetidas e Tukey, Friedman e comparações múltiplas não paramétricas, e Exato de Fisher para comparar as condições de SO entre si. Os testes de *ANOVA* para medidas repetidas e Dunnett foram empregados para comparar os resultados de adaptação em cada condição de SO e a condição controle (α=0,05). Performance e eficiência (5.6 mm) mastigatórias diminuíram gradualmente ($p<0{,}0001$) desde *L1* (X_{50}=5,46±0,64 mm, e 51,21±19,44 %, respectivamente) até *L5* (X_{50}=6,24±0,44 mm, e 24,50±15,98 %, respectivamente). A condição *L4* apresentou menor taxa mastigatória do que a *L1*. As chances para selecionar e fraturar cubos de 8, 4,8 e 2,4 mm igualmente diminuíram ($p<0{,}0001$) à medida que o SO foi reduzido. O padrão de ciclo mastigatório foi similar ($p>0{,}05$). Os indivíduos adaptaram sua performance e eficiência (4 e 2,8 mm) mastigatórias até *L3* apresentando valores similares à condição controle ($p<0{,}05$). Considerando a peneira de 2 mm, os indivíduos também mostraram adaptação em *L4* ($p<0{,}05$). Apenas em *L2*, os indivíduos apresentaram adaptação da taxa mastigatória, chance de seleção e função de fratura ($p<0{,}05$). A redução súbita do suporte oclusal ocasionou a diminuição da performance e eficiência mastigatória devido à deterioração da capacidade de selecionar e fraturar o Optocal. Porém, os indivíduos avaliados adaptaram sua função mastigatória a arcos dentais reduzidos até pré-molares.

Palavras-chave: Suporte oclusal, função mastigatória, prótese parcial removível, prótese total removível

ABSTRACT

Scientific evidences to determine the influence of rehabilitated occlusal support (OS) on masticatory function are insufficient. The aim of this study was to evaluate the influence of OS on masticatory function of removable denture wearers. Twenty three edentulous subjects (mean age=54.2±8.3 years) were rehabilitated with maxillary complete denture and mandibular removable partial denture (RPD). Five OS conditions were determined through wearing of RPD teeth: full OS *(L1*–control condition*)*, OS to 1° molar *(L2)*, to 2° premolar *(L3)*, to 1° premolar *(L4)*, and absence of occlusal support *(L5)*. Masticatory performance and efficiency were evaluated by chew of Optocal cubes edged 5.6 mm using 20 masticatory cycles. Masticatory performance was evaluated through median particle size (X_{50}) using the sieve method (0.5 – 5.6 mm mesh). Masticatory efficiency was determined through test food percentage by weight that passed through sieve of 5.6, 4, 2.8 and 2 mm mesh. The number of masticatory cycles effected per minute was defined as chewing rate. Selection chances and breakage functions were evaluated performing one masticatory cycle simultaneously to Optocal cubes edged 8, 4.8 and 2.4 mm. Masticatory cycle pattern was qualitatively analyzed through its trajectory and quantitatively evaluated through maximum openings and areas recorded using kinesiographic. In the first part of work, the impact of each OS condition was evaluated. In a second stage, the adapting to each OS condition were weekly evaluated. Then, variables were measured immediately after determining each condition, and after one week using the prostheses in the same conditions. It was applied *ANOVA* for repeated measures and Tukey tests, Friedman and nonparametric multiple comparisons tests, and Fisher's exact test to compare the OS conditions between them. *ANOVA* for repeated measures and Dunnett tests were used to compare the adaptation results at each OS and control conditions (α=0.05). Masticatory performance and efficiency (5.6 mm) gradually decreased ($p<0.0001$) from *L1* (X_{50} = 5.46 ± 0.64 mm, and 51.21 ± 19.44 %, respectively) to *L5* (X_{50} = 6.24 ± 0.44 mm, and 24.50 ± 15.98 %, respectively). The *L4* condition showed lower chewing rate than the *L1*. Chances to select and break cubes sized 8, 4.8 and 2.4 mm also decreased ($p<0.0001$) as OS was shortened. Masticatory cycle pattern was similar ($p>0.05$). Subjects adapted their masticatory performance and efficiency (4 and 2.8 mm) until *L3* presenting similar values to control condition ($p<0.05$). According to sieve 2 mm mesh, subjects also showed adaptation in *L4* ($p<0.05$). Only in L2, subjects presented adaptation for chewing rate, selection chance and breakage function ($p<0.05$). The sudden reduction of the occlusal support resulted in decreased masticatory performance and efficiency due to deteriorated capacity to select and break the Optocal. However, the evaluated subjects adapted their chewing to shortened dental arches up to premolars.

Key-words: Occlusal support, masticatory function, removable partial denture, removable complete denture

SUMÁRIO

INTRODUÇÃO

A função mastigatória é o processo por meio do qual o alimento é transformado a um estado fatível de ser deglutido (van de Bilt *et al.*, 2006). A transformação mecânica do alimento consiste na sua redução progressiva até que as dimensões das partículas trituradas permitam que estas sejam deglutidas sem produzir danos à faringe, nem tampouco alterar a sequência do processo gástrico (Prinz e Lucas, 1997). Os fatores mecânicos envolvidos na mastigação estão relacionados principalmente às características da cavidade oral que determinam ou modificam a magnitude e o sentido da força mastigatória aplicada no alimento por meio das superfícies oclusais (Lund, 1992). Desta forma, a anatomia articular, a disposição muscular e o tipo de oclusão condicionam ciclos mastigatórios (Koolstra & van Eijden, 2001), que regulados pelo tronco cerebral, são capazes de aplicar eficazmente a força muscular segundo o número de dentes presentes, área oclusal, pontos de contato e angulações cuspídeas sobre o alimento. Este processo é igualmente modificado pelas características mecânicas do próprio alimento, o qual apresenta alterações das suas propriedades após cada ciclo mastigatório executado (van der Bilt, 2011).

Os processos físico-químicos da mastigação envolvem principalmente a formação de um bolo alimentar coeso e o início da digestão do amido e lipídios pela saliva (Mese & Matsuo, 2007). A quantidade e a composição da saliva variam conforme o período do dia e conforme a presença de estímulos, que podem ser olfativos, visuais, mecânicos, térmicos, gustativos ou relativos às condições do indivíduo, como físicos ou psicológicos (Engelen *et al.*, 2007). Tem sido proposto que o bolo alimentar é passível de ser deglutido somente quando este é formado por partículas cujo tamanho, suficientemente pequeno, permite que a força de coesão entre elas supere à força de adesão do bolo alimentar à mucosa oral (Lucas *et al.*, 2002).

O grau de trituração do alimento durante a mastigação pode ser avaliado por meio de testes de performance e eficiência mastigatórias. A performance mastigatória é definida como o tamanho mediano de partícula obtido por um número determinado de ciclos mastigatórios (van der Bilt, 2011). O teste de performance mastigatória permite analisar a distribuição das partículas trituradas segundo seu tamanho e peso (van der Bilt & Fontijn-Tekamp, 2004). Por outro lado, a eficiência mastigatória representa o peso das partículas trituradas que são menores que um tamanho pré-determinado, permitindo desta forma, realizar comparações das porcentagens obtidas por diferentes indivíduos (van der Bilt & Fontijn-Tekamp, 2004). Ambos os testes se complementam e são utilizados segundo as características da população de estudo.

A distribuição do tamanho e do peso das partículas trituradas pode ser explicada por meio da chance de seleção e função de fratura. A chance de seleção é definida como a probabilidade que partículas de alimento de uma determinada dimensão possuem de serem colocadas entre os dentes para serem em seguida trituradas. Esta depende da forma e dimensão dos dentes, da dinâmica mandibular, dos tecidos moles, e do número e tamanho das partículas de alimento (van den Braber *et al.*, 2002). A função de fratura é definida como a proporção em peso destas partículas selecionadas e trituradas, que por sua vez depende da angulação cuspídea, da força mastigatória e das propriedades físicas e mecânicas do alimento mastigado (van den Braber *et al*., 2005).

Como anteriormente mencionado, durante a função mastigatória o padrão dos movimentos mandibulares é regulado pelo tronco cerebral (Lund, 1992) e modificado por distintas condições da cavidade oral (Neto *et al*., 2007) e textura dos alimentos (Wintergerst *et al*., 2008). Estas modificações dependem em maior parte da retro-alimentação sensorial, a qual determina a coordenação da língua, lábios e dos movimentos mandíbulares ao redor do alimento (Slagter *et al*., 1993). Um registro do ciclo mastigatório bilateralmente amplo no plano frontal, frequência e velocidade constantes, exibindo maior velocidade de abertura e fechamento, e menor duração de contato oclusal durante a fase de máxima intercuspidação, têm sido relacionado a uma ótima performance mastigatória em indivíduos dentados (Wilding & Lewin, 1994; Ow *et al*., 1998; Lepley *et al*., 2010).

Apesar do objetivo do tratamento protético ser a restauração do suporte occlusal e a consequente reabilitação funcional do paciente (Mazurat & Mazurat, 2003a), a mastigação de indivíduos portadores de prótese total superior e prótese parcial removível inferior é alterada devido a fatores protéticos inerentes como retenção, estabilidade e suporte da prótese (Mazurat & Mazurat, 2003b), diminuição da percepção textural da mucosa (Garzino *et al*., 996), e da transmissão da força mastigatória (van der Bilt, 2011). Com o propósito de preservar e diminuir a sobrecarga nos rebordos residuais e dentes suportes durante a mastigação de indivíduos portadores de próteses removíveis tem sido proposto a redução do suporte occlusal (Carr *et al*., 2006). O conceito de arco dental curto considera que o processo adaptativo de indivíduos que apresentem apenas os dentes anteriores e pré-molares em oclusão (naturais ou reabilitados) acarreta uma mastigação adequada, com ausência de desequilíbrio oclusal, trauma occlusal ou disfunção temporomandibular (Kanno & Carlsson, 2006).

Liedberg *et al*., em 2004 consideram que a melhora da mastigação por meio da reabilitação com prótese parcial removível de extremidade livre poderia ser inconsistente, não havendo indicações baseadas em evidência para justificar sua prescrição (Wöstmann *et al*., 2005). Assim, a reabilitação fixa implanto-suportada ou em cantilever até a região de segundos pré-molares pode ser considerada a melhor alternativa de tratamento quando comparadas às próteses removíveis (Jepson *et al*., 2003; Emami & Feine, 2010). Por outro lado, a função que cada par oclusal artificial exerce em uma prótese removível também não está determinada (Yoshimura *et al*., 2006).

A reabilitação do suporte oclusal na região dos dentes molares por meio de prótese parcial removível parece não incrementar a performance mastigatória em indivíduos com perda bilateral de molares inferiores e dentição superior completa (Aras *et al*., 2009). Porém, Yanawaga *et al*., em 2004 e Yoshimura *et al*., em 2006, encontraram que indivíduos com ausência unilateral de molares inferiores, dentição superior completa e reabilitados com prótese parcial removível reduzindo até 10 mm o comprimento e 5 mm a largura do suporte oclusal na região molar, respectivamente, apresentaram menor capacidade para misturar e amassar cubos de parafina, mastigando unilateral e restritamente só no lado do suporte oclusal reabilitado com a prótese parcial removível.

Apesar da pouca informação disponível sobre indivíduos com perda total do suporte oclusal posterior e reabilitados com prótese parcial removível, é sugerido que a menor performance mastigatória apresentada por portadores de prótese total bi-maxilar pode ser explicada devido a menor chance de seleção e função de fratura apresentadas por estes indivíduos (Slagter *et al*., 1993). Com relação ao padrão do ciclo mastigatório, Tallgren *et al*., em 1989 determinaram que indivíduos reabilitados com prótese total superior, e parcial removível inferior de extremo livre são caracterizados por trajetórias de ciclo mastigatório mais regulares e estreitas no plano sagital, e maior abertura máxima vertical, quando comparados com indivíduos não reabilitados. Este padrão de ciclo mastigatório caracteriza a mastigação do bolo alimentar nas regiões posteriores do suporte occlusal, o qual tem sido descrito em estudos de cineradiografia (Hedegård *et al*., 1967), sugerindo desta forma a influência da reabilitação com prótese parcial removível na recuperação da função mastigatória.

Na odontologia baseada em evidências, onde toda terapêutica deve apresentar uma justificativa biológica, é preciso determinar de que maneira os dentes artificiais influenciam a função mastigatória. Assim, o primeiro objetivo desta tese foi avaliar a influência da extensão do suporte oclusal na performance, eficiência e taxa mastigatórias, chance de seleção, função de fratura, e padrão do ciclo mastigatório de portadores de prótese parcial removível de extremo livre. Por outro lado, já que as necessidades funcionais podem variar consideravelmente entre indivíduos (Walther, 2009), e o tratamento de cada caso deve ser adequado às habilidades de adaptação individuais, a segunda proposta foi analisar a adaptação mastigatória a diferentes extensões de suporte oclusal. Esta tese foi desenvolvida com a finalidade de obter dados que ofereçam maior controle sobre os tratamentos protéticos efetuados, determinando a provável melhoria funcional oferecida pela reabilitação por meio de prótese parcial removível.

CAPÍTULO 1. Influence of occlusal support length of free-end removable partial dentures on masticatory function

Alfonso Sánchez-Ayala, MS[a], Glaucia Maria Bovi Ambrosano, PhD[b], Renata Cunha Matheus Rodrigues Garcia, PhD[c]

[a]Graduate Student, Department of Prosthodontics and Periodontology, Piracicaba Dental School, State University of Campinas.

Avenida Limeira nº 901, Piracicaba, São Paulo, 13414-903 – Brazil.

[b]Professor, Department of Social Dentistry, Piracicaba Dental School, State University of Campinas.

Avenida Limeira nº 901, Piracicaba, São Paulo, 13414-903 – Brazil.

[c]Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, State University of Campinas

Avenida Limeira nº 901, Piracicaba, São Paulo, 13414-903 – Brazil.

Corresponding author:

Renata Cunha Matheus Rodrigues Garcia

Department of Prosthodontics and Periodontology, Piracicaba Dental School, State University of Campinas.

Avenida Limeira, nº 901, Bairro Areião, Piracicaba, SP, Brazil, CEP: 13414-903, Phone Number: + 55 19 2106-5240 Fax number: + 55 19 2106-5211.

e-mail: regarcia@fop.unicamp.br

Abstract

Purpose: To determine the influence of occlusal support length (OSL) of free-end removable partial dentures (RPD) on masticatory function. **Materials and Methods:** Twenty-three subjects (mean age = 55.2 years ± 8.4) who were edentulous in the maxilla and classified as Kennedy Class I in the mandible were selected. Subjects received new maxillary complete dentures and mandibular RPDs. Five OSL conditions were determined by RPD artificial teeth wear: full occlusal support (L1-control), OSL to first molar (L2), to second premolar (L3), to first premolar (L4), and absence of occlusal support (L5). Masticatory performance and efficiency were evaluated using the sieve method. The number of masticatory cycles per minute was defined as chewing rate. Bolus selection chances and bolus breakage function were evaluated using the one-chew method. Qualitative and quantitative measurements of masticatory cycle patterns were kinesiographically recorded. Data were analyzed using repeated measures ANOVA, Friedman and Fisher's exact tests ($\alpha = .05$). **Results:** Masticatory performance and efficiency decreased ($P < .05$) from L1 (5.46 ± 0.64 mm, and 51.21 ± 19.44 %, respectively) to L5 (6.24 ± 0.44 mm, and 24.50 ± 15.98 %, respectively). Chewing rate was higher for L4 when compared to L1 ($P < .05$). Bolus selection chances and bolus breakage functions also decreased as OSL was reduced ($P < .05$); however, there were no differences in masticatory cycle pattern among the OSL conditions ($P > .05$). **Conclusion:** Reduction of OSL altered masticatory function, thereby decreasing masticatory performance and efficiency due to a lower capacity to select and break down the food.

Keywords: Removable partial denture, occlusal support, masticatory performance, masticatory cycle pattern, chewing rate

Introduction

The main goal of prosthetic rehabilitation is to replace lost teeth in order to restore a sufficient number of occlusal surfaces to promote occlusal support and efficient mastication.[1] The functional improvement of partially edentulous subjects through rehabilitation with the use of removable partial dentures (RPD) is not clear,[2] and there are still no evidence-based indications to justify their prescription.[3] This may be due to a lack of data regarding the influence of occlusal support on masticatory function, given that the artificial teeth are considered as a nonspecific splinted grinding tool.[4,5] Reduction of the occlusal support length of free-end RPDs has been suggested in order to preserve and decrease the overload on the residual ridges and abutment teeth during mastication.[6] According to the shortened arch concept, the rehabilitation of occlusal support can be restricted to restoring the arches only to the level of second premolars.[7-9]

The influence of occlusal support on masticatory function can be described through masticatory performance and masticatory efficiency tests, which determine the comminution degree in terms of median particle size and percentage of efficiency, respectively.[10] The results of both tests depend on the individual chewing rate applied during mastication,[11] which can be modified by oral or food characteristics.[12] Reduction in occlusal support of molar unilateral free-end RPDs occluding on natural teeth can decrease the capacity to mix and knead food.[4,5]

However, there are no studies either on the influence of free-end length of RPD on masticatory performance, or the chewing efficiency of subjects who lost bilateral occlusal support in both maxillaries.

During chewing, each cycle starts with the selection process of viable particles to be broken and ends when a breakage process is completed.[8] Any alteration in selection or breakage may alter the masticatory performance and efficiency, according to the constantly changing properties of food particles after each masticatory cycle.[13] Selection chance is the probability that food particles are captured by the teeth. Breakage function is the process by which selected particles are fractured into fragments of different sizes. Studies have shown that complete denture wearers present smaller values for both selection chance and breakage function when compared to dentate subjects,[14,15] however, there are no available data for RPD wearers.

The masticatory function of subjects rehabilitated by RPDs can also be evaluated by the analysis of trajectories, maximum excursions and areas of mandibular movements during mastication.[16] The mandibular movements are connected with hyoid and tongue movements, and therefore with food transport in the mouth,[17] which can also be altered according to loss of occlusal support.[8] Tallgren et al.[16] found that complete upper and partial lower Kennedy Class I denture wearers are characterized by more regular and some narrowed sagittal masticatory cycles, presenting an increased maximal vertical opening, which characterizes the mastication of a food bolus in the posterior region of rehabilitated dental arches.[18]

Considering that any prosthodontic procedure should be biologically justified, the objective of this study was to evaluate the immediate influence of reducing occlusal support length on masticatory performance and efficiency, chewing rate, selection chance, breakage function, and patterns of the masticatory cycle of free-end partial removable denture wearers. Clearly defining the values of such properties will establish the improvement afforded by this type of rehabilitation.

Materials and Methods

Sixty-three partially dentate subjects were initially recruited from Piracicaba Dental School, State University of Campinas services. After clinical examination, twenty-three subjects (5 males and 18 females, mean age 55.2 years ± 8.4 years), were selected to participate in this study. To be selected, subjects must present the following criteria: (1) total edentulism in the maxilla, and partial edentulism in the mandible, classified as Kennedy Class I, presenting canines and incisive teeth; and (2) slight or moderate bone resorption of residual ridges. Subjects with neuromuscular diseases, or who presented with symptoms of temporomandibular diseases, parafunctional habits, xerostomy, and severe periodontal disease were excluded. The research protocol was approved by the Ethics Committee of Piracicaba Dental School, State University of Campinas and a written consent was obtained from all participants.

All selected subjects received a general dental treatment including periodontal and dental care of remaining teeth, and prosthetic rehabilitation with conventional complete dentures in the maxilla and free-end RPDs in the mandible. The RPDs were manufactured with Co-Cr metal frame-works, and according to height from the floor of the mouth to the free gingival margins, lingual plates or lingual bars were used as the major connectors. The direct retainers were circumferential or bar clasps, based upon the retention and contour of abutment teeth. A heat-cured acrylic resin (Dental Vipi, Pirassununga, SP, Brazil) was used to process denture bases. The occlusal support of dentures was established through second molars (Dentsply Industria Ltd., Petropolis, Brazil), and a bilateral balanced occlusal scheme was employed. This occlusal scheme was prior achieved through artificial teeth adjustments on wax rims during functional and aesthetic proofs of maxillary and mandibular dentures. After dentures processing, if it was necessary, new adjustments were done during the insertion dentures session, by wear of artificial teeth from the complete denture. All prosthetic treatments were performed by the same operator, and after insertion of new dentures, the subjects had a two-month period of adaptation before beginning evaluation of masticatory functions.

Evaluation of masticatory performance, masticatory efficiency and chewing rate

Optocal artificial test food based on Optosil® polydimethylsiloxane putty (Optosil® Comfort®, Heraeus Kulzer GmbH & Co., KG, Germany) was used to prepare cubes measuring 5.6 mm on each edge.[15,19] Portions of 17 cubes (approximately 3 cm^3 and 3.7 g) were offered to the subjects, who were instructed to chew them in a habitual way. After 20 chewing strokes, counted by the examiner, the particles were expectorated on a paper filter sitting on a glass container, followed by mouth rinsing with 200 ml of water to complete cleansing of the oral cavity. The comminuted particles were recovered and were dried at room temperature for a week, then sieved in a sieving machine (Bertel Indústria Metalúrgica, Caieiras, SP, Brazil) through a stack of up to 10 sieves, using mesh sizes gradually decreasing from 5.6 mm to 0.5 mm, for 20 minutes. The particles retained on each sieve and in the bottom pans were weighed on a 0.001 g analytical balance (Mark, Bel Engineering, Monza, Milano, Italy).

Masticatory performance was determined according to the median particle size (X_{50}) calculated using the Rosin-Rammler cumulative function.[10] Masticatory efficiency was calculated as the weight percentage of the fractioned material that passed through the 5.6 mm mesh.[15] When recording the subjects' masticatory cycles, the time to complete 20 masticatory cycles was registered, and then the chewing rate was defined as the number of masticatory cycles performed per minute.[11]

Selection chance and breakage function of bolus

Bolus selection chance and bolus breakage function for different particle sizes were determined by the One-Chew experiment.[20] Three sizes of Optocal cubes with edges measuring 8.0 mm, 4.8 mm, and 2.4 mm were prepared as previously described.[21] Each subject was offered simultaneously 3 cubes of 8.0 mm, 12 cubes of 4.8 mm, and 68 cubes of 2.4 mm.[19,22] Subjects first made pseudo-chewing movements to obtain a natural dispersion of the particles in the mouth and to produce saliva. Thereafter, they were instructed to carry out a real chew.[21] Afterward, the particles were expectorated into a filter paper and the mouth was rinsed with 200 ml of water to complete cleansing of the oral cavity. Since all particles initially had regular shapes, the non-damaged (non-selected) particles were distinguished in damaged and broken (selected) ones by visual inspection.[20] The weight of the selected particles divided by the total weight of damaged and non-damaged particles corresponds to the selection chance of each size. After sieving and weighing the particles, breakage function was defined through a cumulative distribution function, which establishes the degree of fragmentation (r).[20-22]

Masticatory cycle pattern

Masticatory cycle patterns were recorded simultaneously with masticatory performance and efficiency evaluations during 20 cycles, using a kinesiograph (K6-I Evaluation System, Myotronics-Noromed Inc., Kent, WA, USA)., Subjects were seated on a chair with the Frankfort plane parallel to the ground; a small magnet was attached to their lower central incisors, and the mandibular scanner was installed on the subject’s head. Trajectories of mandibular movements were assessed and classified in the frontal plane as: tear-drop (Type I); hemi-oval (Type II); and the sliver (Type III).[23] In the sagittal plane, mandibular movements were classified according to the maximal anteroposterior width between opening and closing path configurations as either less than 2 mm (Type I) or more than 2 mm (Type II).[23] Maximum frontal, horizontal, and anteroposterior excursions (mm), and frontal and sagittal areas (mm^2) of the masticatory cycle were recorded and defined as quantitative measurements, which were analyzed using Image Tool Software (University of Texas Health Science Center, San Antonio, TX, USA).

Occlusal support length and periods of valuations

Variables were first measured 2 months after the insertion of new dentures with full occlusal support length until the second molars (L1, considered as controls). After L1 evaluation, the occlusal support length of the inferior RPDs was reduced to the first molars (L2), and all variables were re-evaluated. The sequential evaluations were carried out weekly, in three additional sessions, reducing the occlusal support length as follows: occlusal support length to second premolars (L3); occlusal support length to first premolars (L4); and finally, absence of occlusal (L5). The reduction of occlusal support length of the RPDs was performed by artificial teeth wear, using a low speed cylindrical tungsten bur (Maxi Cut, Edenta, SP, Brazil). All evaluations were carried out immediately after each tooth removal, and no time was allowed to subject adapt to the new occlusal condition. After each evaluation, another artificial tooth was replaced in infra-occlusion at the denture base level.

Statistical analysis

Assumptions of parametric analysis were tested for data, according to additivity model, homogeneity of variances, and normality of residuals through guided data analysis with SAS statistical software (SAS, 2008). Masticatory performance was transformed to square, and logarithmic transformation was applied to data from the frontal and sagittal areas, and to the chewing rate. After that, ANOVA for repeated measures and post-hoc Tukey tests were applied for the mentioned variables and the maximum excursions data. Selection chance and breakage functions did not meet the assumptions necessary for parametric analysis, therefore they were evaluated by Friedman's test and non-parametric multiple comparisons tests. The qualitative measurements of masticatory cycle patterns were analyzed using Fisher's exact test. All statistical analyses tests were performed assuming a 5% significance level.

Results

Masticatory performance (X_{50}) and masticatory efficiency (%) gradually decreased (from 5.46 mm ± 0.64 mm to 6.24 mm ± 0.44 mm; and from 51.21 % ± 19.44 % to 24.50 % ± 15.98 %, respectively) from RPDs presenting full occlusal support length (L1) to RPDs with no occlusal support (L5). Significant differences ($P < .05$) were noted among L1 (control), L4, and L5 conditions (Table 1). Despite these data, comparisons of chewing rate among subjects showed similar values ($P > .05$) for all occlusal support lengths, except for the differences ($P < .05$) noted between values measured for subjects in conditions L1 and L4, who presented the lowest and the highest ($P < .05$) chewing rates, respectively (Table 1).

The percentage of selection chance for cubes sized 8 mm, 4.8 mm, and 2.4 mm also decreased when the occlusal support was reduced (Table 2). There were differences ($P < .05$) among L1, L3 and L5 lengths of occlusal support, with the lowest values presented by subjects in the last condition. It can also be noted that subjects in condition L2 showed a greater ($P < .05$) chance of selecting particles than subjects in conditions L4 and L5. Results of the breakage function test for particles sized 8 mm were similar to the data from selection chance (Table 2). However, for particles sized 4.8 mm and 2.4 mm, subjects in conditions L4 and L5 presented lower breakage function values ($P <. 05$) than the other conditions (Table 2).

The pattern of mandibular movements during mastication was not altered ($P > .05$) among the oclusal support lengths, in both frontal and sagittal planes (Figure 1, Table 3). Similarly, quantitative values measured for masticatory cycles showed no differences ($P > .05$) among all conditions of occlusal support length (Table 4).

Discussion

Masticatory performance and efficiency showed decreased values when subjects chewed using free-end RPDs with reduced occlusal support length. Although no studies have examined the influence of artificial premolars and molars on the masticatory performance and efficiency of RPD wearers, the results of this study are in agreement with those from Yanagawa *et al.*,[4] who observed decreased masticatory performance when the length of the food platform in Kennedy Class II free-end RPDs was reduced to 10 mm. In addition, similar results were showed by overdenture wearers, with the masticatory performance decreasing after reduction of occlusal support length to second and first premolars.[24]

In this study, masticatory function was different after removal of the second molars from free-end RPDs (condition L2). A decrease in the capacity to comminute test food can be due to loss of occlusal contact and reduced transmission of masticatory force,[25,26] which are the main determinants of masticatory function.[27] Loss of the molar teeth results in decreased comminution of particles of around 4.8 mm or smaller, which influence the cumulative weight distribution during median particle size estimation.[28] However, no differences were noted among subjects in conditions L2, L3 and L4, emphasizing the probable importance of the presence of the second molar when processing mandibular free-end RPDs. The lack of differences among these conditions may result from the gradual increase in bite force at second and first premolars after loss of contact at first molar and second premolar levels, respectively,[29] which could improve the comminution capacity. However, despite the higher force on remaining teeth, the total bite force or the sum of occlusal load distributed over the dentition decreases due to the lower number of occluding antagonist teeth,[30] explaining the higher masticatory performance and efficiency values showed by controls. Moreover, since a reduced occlusal support length also implies in the reduction of total occlusal table area,[31] an increased bite force by a higher local stressing to indent or crack the food for the same applied muscular load[28] may be considered mainly to harder food.[32] Nevertheless, the lower number of antagonist teeth also decreases the capacity to select particles and the number of available breakage sites[14], limiting the use of the increased bite force on remaining teeth.

Despite the differences in masticatory tests, subjects with different occlusal support length presented similar chewing rates, except for comparisons between the controls and condition L4. The duration of each masticatory cycle depends on the ease of breaking down the food,[12,33] and comminution capacity is high when a slow chewing rate is performed.[11] Subjects with reduced occlusal support length could compress fewer food particles between artificial teeth; therefore, they have lower resistance to reach maximum intercuspation.[33] As a consequence, the velocity for completion of each masticatory cycle may be increased.

Given that premolars provide preliminary breakdown from large and medium sized particles, and molars reduce the particle size further,[28] the presence of all premolars in conditions L2 and L3 likely leads to the absence of alteration of the chewing rate. In addition, the lack of difference in chewing rate between values measured for conditions L1 and L5 could be due to the anteriorized chewing presented by subjects without occlusal support.[18] Without posterior contacts (condition L5), the bite force of anterior teeth increases, and is similar to that in the molar region when the occlusal support is intact.[30] Despite the fact that bite force was not measured in this study, this may be considered as a compensation mechanism and probably reduces or eliminates an alteration of chewing rate in condition L5.

Selection chance of cubes sized 8 mm, 4.8 mm, and 2.4 mm also decreased corresponding to reduction of occlusal support length. The selection chance is determined by tongue and cheek action, tooth shape, occlusal area, and size and number of food particles.[22] There are no reports about selection chance in free-end removable denture wearers, but it is likely that the reduced occlusal area that is a consequence of the progressive reduction of occlusal support leads to a lack of coordination among tongue, cheeks, and artificial and remaining teeth. As previously mentioned, this condition could indicate that the food particles cannot be selected, decreasing the quantity of food particles trapped between the teeth due to escape between occlusal surfaces without breaking during mastication.[14]

Breakage function depends on cusp form, masticatory force, and fracture characteristics of food.[20] Thus, after a gradual reduction of occlusal support length, breakage could be decreased by the fewer particles that were previously selected[14,15] and lower transmission of masticatory force through the remaining teeth.[29,30] Decline of breakage function was more critical for cubes sized 4.8 mm and 2.4 mm, which showed values near to zero. This is according to van den Braber et al.,[20] who found that subjects with poor masticatory performance due to altered occlusion showed more difficulty in selecting and breaking Optosil cubes, and may explain why these subjects increase the number of masticatory cycles before swallowing, or swallow larger particles.[34] Also, the decreased oral sensory perception and feedback presented by edentulous subjects, even after rehabilitation, could contribute to the lower values of selection chance and breakage function observed in this study.[35] According to our results, selection chance and breakage function reflected the masticatory performance and efficiency values reached by subjects in the different occlusal support conditions.

The pattern of mandibular movements during chewing did not differ among the different posterior occlusal support lengths on both frontal and sagittal planes. The same results were obtained for the maximum mandibular excursions and areas of masticatory cycles. These findings are in agreement with Nissan *et al.*,[36] who found that factors such as missing teeth, occlusion type, lateral guidance, gender, implant-supported restorations and complete dentures use do not affect the trajectory of the masticatory cycle. Apparently, there are other factors besides occlusal support that can influence mandibular movement during mastication by free-end removable denture wearers. These factors could be related to musculoskeletal features[37] such as articular kinematics[38] and muscle lines of action,[39] as well as variations on the central control of the masticatory cycle.[40]

Although the occlusal support is a structural feature that should be rehabilitated during prosthetic treatment,[24,27] it should be considered that subjects could adapt their mastication to new occlusal conditions, without oral discomfort, occlusal instability, temporomandibular signs and symptoms and others.[7] However, an adaptation period was not considered in the present study, being the masticatory function immediately evaluated after each variation of oclusal support. If an adaptive period was included, the cumulative contribution of each restored artificial tooth couldn't be determined, since compensatory mechanisms may alter the results. Undoubtedly, controlled studies evaluating rationale adaptive periods must be conducted in order to determine the adaptation degree of subjects, and whether this can be temporarily sustainable without masticatory system fatigue.

Within the limitations of this study, it can be concluded that any reduction of occlusal support length for free-end RPD wearers can influence masticatory function, decreasing masticatory performance and efficiency due to a reduced capacity to select and break the food. However, the length of occlusal support did not change mandibular movement during mastication.

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Table 1. Masticatory performance, masticatory efficiency, and chewing rate values (mean ± SD)

Occlusal support lengths	Masticatory performance (mm)	Masticatory efficiency (%)	Chewing rate (cycles/min)
L1 (Full occlusal support)	5.46 ± 0.64A	51.21 ± 19.44A	82.21 ± 14.68A
L2 (until 1^{o} molars)	5.84 ± 0.55B	39.33 ± 17.59B	83.81 ± 14.72AB
L3 (until 2^{o} premolars)	5.91 ± 0.54B	36.33 ± 19.25B	88.16 ± 17.80AB
L4 (until 1^{o} premolars)	6.11 ± 0.52BC	29.67 ± 19.86BC	89.45 ± 18.89B
L5 (Without occlusal support)	6.24 ± 0.44C	24.50 ± 15.98C	87.27 ± 15.26AB

Different letters show statistical differences among occlusal support lengths ($P < .05$)

Table 2. Selection chance and breakage function values (mean ± SD)

Occlusal support lengths	Selection chance			Breakage function (r)		
	Size of cubes (mm)			Size of cubes (mm)		
	8	4.8	2.4	8	4.8	2.4
L1 (Full occlusal support)	0.90 ± 0.16A	0.41 ± 0.10A	0.07 ± 0.02A	0.39 ± 0.10A	0.19 ± 0.08A	0.05 ± 0.03A
L2 (until 1° molars)	0.77 ± 0.19AB	0.28 ± 0.09AB	0.04 ± 0.01AB	0.38 ± 0.12AB	0.13 ± 0.06AB	0.03 ± 0.03A
L3 (until 2° premolars)	0.52 ± 0.17BC	0.18 ± 0.09BC	0.03 ± 0.02BC	0.27 ± 0.17BC	0.09 ± 0.05B	0.03 ± 0.04A
L4 (until 1° premolars)	0.43 ± 0.21CD	0.11 ± 0.10CD	0.01 ± 0.03CD	0.19 ± 0.16CD	0.02 ± 0.04C	0.00 ± 0.00B
L5 (Without occlusal support)	0.33 ± 0.10D	0.05 ± 0.09D	0.00 ± 0.00D	0.02 ± 0.06D	0.00 ± 0.00C	0.00 ± 0.00B

Different letters show statistical differences among occlusal support lengths ($P < .05$)

Table 3. Patterns of mandibular movements recorded by kinesiography

Occlusal support lengths	Mandibular movement during mastication (%)				
	Frontal plane			Sagittal plane	
	Type 1	Type 2	Type 3	Type 1	Type 2
L1 (Full occlusal support)	20 (87.0)	3 (13.0)	0 (0.0)	0 (0.0)	23 (100.0)
L2 (until 1° molars)	19 (82.6)	4 (17.4)	0 (0.0)	0 (0.0)	23 (100.0)
L3 (until 2° premolars)	18 (78.3)	5 (21.7)	0 (0.0)	1 (4.4)	22 (95.6)
L4 (until 1° premolars)	21 (91.3)	2 (8.7)	0 (0.0)	0 (0.0)	23 (100.0)
L5 (Without occlusal support)	20 (87.0)	3 (13.0)	0 (0.0)	0 (0.0)	23 (100.0)

No differences was found among occlusal support lengths ($P > .05$)

Table 4. Quantitative masticatory cycle measurements (mean ± SD) according to the occlusal support lengths

Occlusal support lengths	Maximum excursions (mm)			Area (mm^2)	
	Vertical	Horizontal	Anteroposterior	Frontal	Sagittal
L1 (Full occlusal support)	18.16 ± 4.49	11.54 ± 3.12	6.63 ± 1.64	126.30 ± 59.35	59.63 ± 19.56
L2 (until 1° molars)	18.30 ± 4.74	12.37 ± 3.28	7.02 ± 2.04	139.50 ± 72.56	63.26 ± 24.09
L3 (until 2° premolars)	18.04 ± 3.86	11.43 ± 2.87	6.76 ± 2.11	128.71 ± 61.65	59.28 ± 21.08
L4 (until 1° premolars)	18.16 ± 4.06	11.22 ± 3.00	6.81 ± 1.84	125.90 ± 59.63	59.89 ± 21.54
L5 (Without occlusal support)	18.19 ± 4.57	10.88 ± 3.28	6.78 ± 1.78	118.46 ± 69.97	57.93 ± 21.28

No differences were found among occlusal support lengths (*P* > .05)

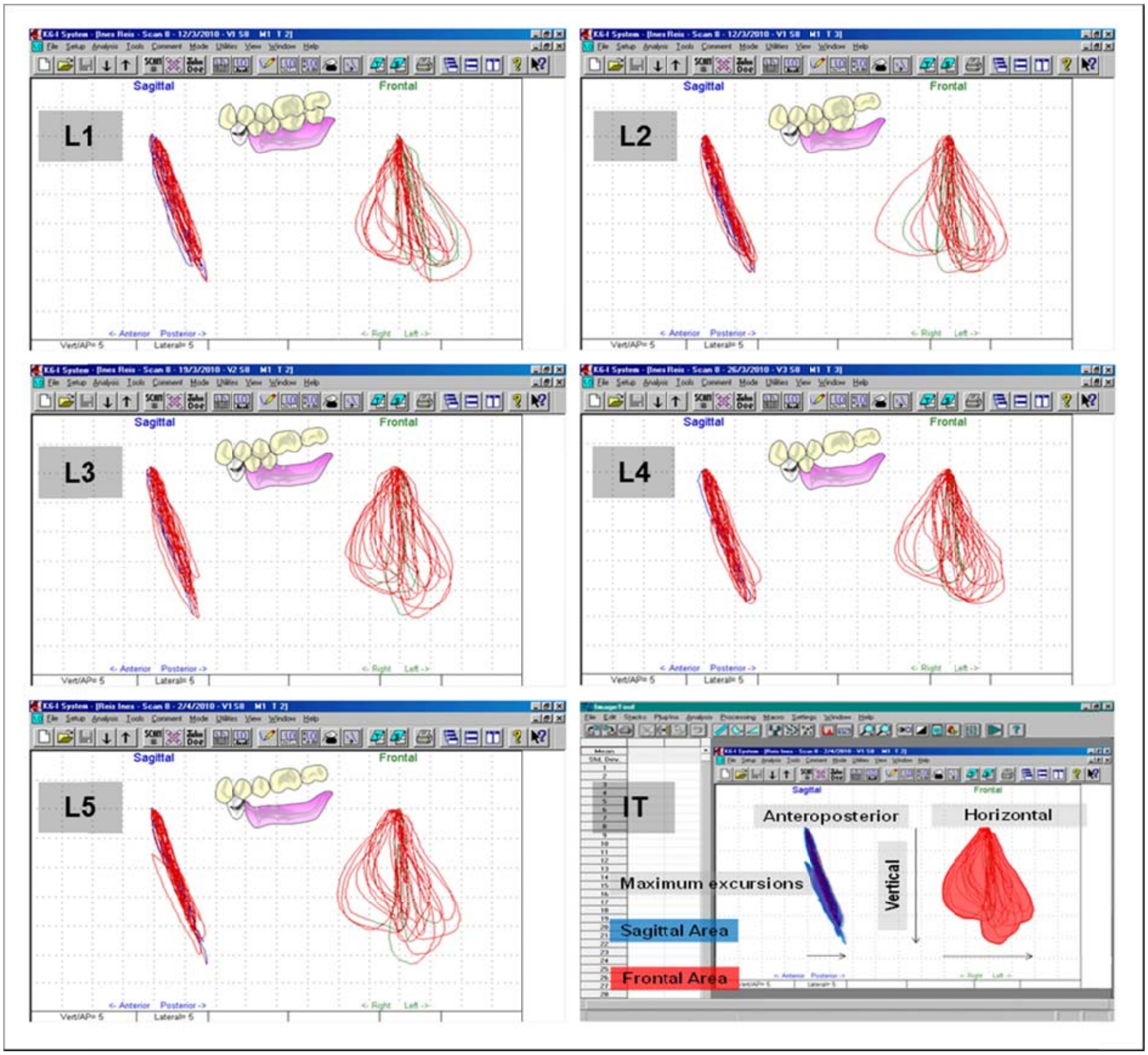

Figure 1. Masticatory cycle patterns according to each occlusal support condition. L1: Full occlusal support; L2: until 1° molars; L3: until 2° premolars; L4: until 1° premolars; L5: Without occlusal support; IT: Analysis performed using Image Tool Software.

CAPÍTULO 2. Title: Chewing adaptation to artificially shortened dental arches

Running title: Adaptation to shortened dental arches

Keywords: removable partial denture, occlusal support, masticatory function

Alfonso Sánchez-Ayala, MS[a], Glaucia Maria Bovi Ambrosano, PhD[b], Renata Cunha Matheus Rodrigues Garcia, PhD[c]

[a]Graduate Student. Department of Prosthodontics and Periodontology, Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil.

[b]Professor. Department of Social Dentistry, Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil.

[c]Professor. Department of Prosthodontics and Periodontology, Piracicaba Dental School, State University of Campinas, São Paulo, Brazil.

Corresponding author:

Dr. Renata Cunha Matheus Rodrigues Garcia

Department of Prosthodontics and Periodontology

Piracicaba Dental School, State University of Campinas

Avenida Limeira, nº 901, Piracicaba, São Paulo, Brazil,,13414-903

Phone number: + 55 19 2106-5240 / Fax number: + 55 19 2106-5211

e-mail: regarcia@fop.unicamp.br

Summary

The aim of this study was to analyze chewing adaptation to artificially shortened dental arches of removable partial dentures. Twenty-three edentulous subjects were rehabilitated with maxillary complete and mandibular free-end removable partial dentures, restoring arches up to the second molars (control). Four categories were determined: *(1)* slightly shortened dental arch (occlusal support to first molars), *(2)* shortened dental arch (to second premolars), *(3)* extremely shortened dental arch (to first premolars), and *(4)* absence of occlusal support. Chewing adaptation was weakly evaluated as masticatory performance, masticatory efficiency, chewing rate, selection chance, and breakage function, in subjects in all occlusal categories, by Optocal chewing and the sieving method. Data were analyzed using repeated measures ANOVA and post-hoc Dunnett tests ($\alpha = 0.05$). In the shortened dental arch category, subjects adapted their masticatory performance and efficiency to particles from 2 to 4 mm and showed similar values to control conditions ($p > 0.05$). Masticatory efficiency adaptation to particles smaller than 2 mm was also seen in the extremely shortened dental arch category ($p > 0.05$), and results of chewing rate showed adaptation only for slightly shortened dental arch condition ($p > 0.05$). Adaptation was also noted for selection chance of particles sized 8 mm in the slightly shortened dental arch category ($p > 0.05$). Breakage function data revealed adaptation for particles sized 8 and 2.4 mm ($p > 0.05$) for the same anterior condition. It can be considered that there was chewing adaptation to shortened dental arches up to the artificial premolars.

Introduction

The shortened dental arch (SDA) concept considers that partially edentulous subjects have sufficient chewing adaptive capacity if at least the anterior and four occlusal units are left without rehabilitation (1). In this model, one occlusal unit corresponds to a pair of occluding premolars, and two occlusal units correspond to a pair of occluding molars (2). Therefore, premolar teeth are indispensable for maintaining a satisfactory, although still suboptimal level of oral function (3).

The absence of molar support does not appear to cause signs and symptoms of temporomandibular disorders or migration of remaining teeth, or decrease in masticatory ability, oral comfort, periodontal support, or occlusal stability (3, 4). Therefore, for subjects who have adapted to the absence of molars, there is no functional reason to recommend prosthetic appliances that extend the arches up to the molars (5, 6). In addition, no well-defined recommendations exist for SDA management according to extension (7), but subject perception about masticatory function impairment because of missing occlusal units is believed to be a critical factor for treatment (8).

Chewing adaptation can be measured with masticatory performance and efficiency tests, which are determined by differences in chewing rate, selection chance, and breakage function (9). Food particles are rhythmically selected and placed in the available breakage sites, which increase proportionally after being broken and decrease when new food particles are successively selected (10). Although this process is altered when teeth are lost, adaptation through the control of mandibular muscles in the primary motor and somatosensory cortexes of rats has been detected one week after incisor removal (11). Compensation of a decreased capacity to comminute can be through different chewing rates or mandibular and soft tissue movements (9), which can generate alternative patterns to bolus transport and increase the selection chance of particles.

The SDA model has been applied to prosthodontic decisions by extending artificial dental arches (3). Priority should be given to maintaining and replacing only the strategically important parts of the arch, ensuring bilateral occlusal support and masticatory function (12), however, evidence on this topic is limited (7). Despite the consideration of SDA implant-support as an alternative treatment (13), Al-Ali et al. (14) showed that the masticatory efficiency of implant-retained overdenture wearers decreased after reduction of dental arches. In some studies (6, 15-17) oral rehabilitation was restricted to restoring the arch to the premolar level, suggesting that cantilever-fixed or implant-supported partial dentures could be more effective treatment for patient comfort and acceptance compared to removable partial dentures (RPD).

Improvement in masticatory performance through oral rehabilitation by bilateral free-end RPD insertion can be influenced not only by prosthetic factors such as retention, stability and support (18), but also by physiological features such as reduced texture perception (19) and lower transmission of muscle strength through artificial teeth (20); and how SDA patients adapt their oral function to this new oral environment is little known (21). Thus, since the functional requirements of patients can vary considerably and treatment in each case should be adjusted to individual needs and adaptation ability (12), the aim of this study was to analyze chewing adaptation to artificial SDAs of free-end RPD wearers, by means of masticatory performance and efficiency, chewing rate, selection chance, and breakage function tests.

Materials and Methods

Sample

It was recruited 23 subjects (5 males, 18 females, mean age 55.2 ± 8.4 years) from Piracicaba Dental School, State University of Campinas services. A sample size calculation yielded 21 subjects according to the means and standard deviations data of Yanagawa et al. (2004), for a statistical power of 80% ($\alpha = 0.05$, two-tail). Inclusion criteria were total edentulism in the maxilla and Kennedy Class I partial edentulism in the mandible. The presence of all incisive and canines mandibular teeth was also required. Subjects with neuromuscular disease, or who presented with symptoms of temporomandibular diseases, parafunctional habits, xerostomy, severe periodontal disease, or severe bone resorption of residual ridges were excluded. The Ethics Committee of Piracicaba Dental School, State University of Campinas approved the research protocol and a written consent was obtained from all volunteers.

Subjects were rehabilitated with conventional complete dentures in the maxilla and free-end RPDs in the mandible after receiving periodontal and dental care of the remaining teeth from a single operator. RPDs were planned according to individual anatomical characteristics, including lingual plates or lingual bars as major connectors and circumferential or bars clasps as direct retainers. All frame-works were processed using Co-Cr cast metal. The artificial teeth (Dentsply Industria Ltd., Petropolis, Brazil) were mounted on wax rims over a frame-works, and a heat-cured acrylic resin (Dental Vipi, Pirassununga, SP, Brazil) was used to process the dentures bases. The occlusal support was established to the second artificial molars, and a bilateral balanced occlusal scheme was used. Chewing adaptation measurements began two months after insertion of new dentures for masticatory performance, masticatory efficiency, chewing rate, selection chance, and breakage function tests.

Masticatory performance, masticatory efficiency, and chewing rate measurements

Optocal artificial test material was prepared by mixing the components listed in Table 1 in a ceramic mortar (22). Cubes of Optocal were prepared in metallic molds, measuring 5.6 mm on each edge, and completely polymerized in a stove for 16 h at 65°C (23). Each subjects chewed a portion of 17 cubes (approximately 3 cm^3 and 3.7 g) using 20 habitual chewing strokes, counted by the examiner. Comminuted particles were expectorated on a paper filter set on a glass container, followed by mouth rinsing with 200 ml of water to recover all material. Particles were dried at room temperature for one week, then vibrate in a sieving machine for 20 minutes (Bertel Indústria Metalúrgica, Caieiras, SP, Brazil) using a stack of sieves (5.6, 4.75, 4, 3.35, 2.8, 2, 1.4, 1, 0.71, 0.5). Material retained on each sieve and in the bottom pans were weighed on a 0.001 g analytical balance (Mark, Bel Engineering, Monza, Milano, Italy). Masticatory performance was determined by median particle size (X_{50}) calculated using the Rosin-Rammler cumulative function (23). To investigate the behavior of comminuted coarse, medium and fine Optocal particles (24), masticatory efficiency was calculated as the percentage weight of the fractioned material that passed through the 4, 2.8 and 2 mm meshes (25). The number of masticatory cycles performed per minute was defined as the chewing rate. (26).

One-chew experiment to selection chance and breakage function evaluations

Three sizes of Optocal cubes with edges of 8.0 mm, 4.8 mm, and 2.4 mm were prepared as previously described (28). Each subject received 3 cubes of 8.0 mm, 12 cubes of 4.8 mm, and 68 cubes of 2.4 mm simultaneously, and it was requested to made a pseudo-chewing movements to obtain a natural dispersion of all cubes in the mouth and to produce saliva (22, 27-29). After, they were instructed to chew the particles for just one masticatory cycle (28). Particles were then expectorated into a filter paper and the mouth was rinsed with 200 ml of water as above. The non-damaged (non-selected) particles were separated from damaged and broken (selected) particles by visual inspection (27). Selection chance of each size was obtained dividing the weight of the selected particles by the total weight of damaged and non-damaged particles. After sieving and weighing, breakage function was calculated employed a cumulative distribution function, which determined the degree of fragmentation (r) (27-29).

Evaluation periods

Chewing adaptation was first evaluated at baseline, being subjects using the new prostheses with complete artificial teeth (control). After, subjects had their RPDs submitted to the following SDA categories: *(1)* slightly SDA (occlusal support up to first molars), *(2)* SDA (occlusal support up to second premolars), *(3)* extremely SDA (occlusal support up to first premolars), and *(4)* absence of occlusal support; established by wearing the artificial teeth using a low-speed cylindrical tungsten bur (Maxi Cut, Edenta, SP, Brazil). The chewing adaptation tests were again carried out after a period of one week allowed to subject to adapt their mastication to each one of the SDA category (11). For aesthetic reasons, after each artificial tooth wear, another one was placed in infra-occlusion position at the denture base level.

Statistical analysis

Parametric analysis was carried out according to the additivity model, homogeneity of variances, and normality of residuals by guided data analysis with SAS statistical software (SAS, 2008). Median particle size values were transformed to square, and square root transformation was applied to data from masticatory efficiency and breakage function for 2.4 mm cubes. Chewing rate and selection chance data were transformed to base 10 logarithmic. One-way repeated measures analysis of variance and post-hoc Dunnett tests were used to analyze variables. Correlation of masticatory performance and efficiency values was determined by Pearson's correlation test. It was assumed a 5% significance level.

Results

Masticatory performance (mm) and efficiency (%) results, according to artificial each SDA category, are presented in the Table 2. Reduction of the median comminuted particle size in subjects who chewed while wearing their dentures in the slightly SDA and SDA categories was similar to when their RPDs had completely artificial teeth ($p > 0.05$). However, after any additional tooth removal, masticatory performance decreased ($p < 0.05$) compared to control conditions (Table 2). Masticatory efficiency results showed the same trend, however for particles smaller than 2 mm, chewing adaptation was also achieved in the extremely SDA category ($p > 0.05$). In all SDA categories, subjects using RPDs had higher chewing rate values than controls ($p < 0.05$), except for the slightly SDA category ($p > 0.05$) (Table 2).

Median particle size values showed a significant correlation with coarse ($r = - 0.865$) (4 mm sieve mesh), medium ($r = - 0.823$) (2.8 mm sieve mesh), and fine ($r = - 0.769$) (2 mm sieve mesh) particles ($p < 0.0001$).

Selection chance and breakage function data (Table 3) for 8 mm cubes showed no differences ($p > 0.05$) between the slightly SDA RPDs category and controls. In addition, no differences for breakage function were noted between these categories for 2.4 mm cubes. Selection chance for 4.8 mm and 2.4 mm cubes, and breakage function for 4.8 mm cubes showed lower values than control conditions in all SDA categories ($p < 0.05$) (Table 3).

Discussion

Although removing posterior teeth can immediately alter masticatory function (30), in the present study, subjects adapted their mastication after one week of loss of artificial molars, achieving similar values of median particle size and efficiency percentage to control conditions. A possible adaptation to loss of natural molars was also seen by Aras et al. (20), who reported similar masticatory performance among subjects with natural SDA presenting time of edentulousness between 4 and 9 and free-end RPDs wearers with an adaptation period of 8 weeks to new dentures.

Chewing adaptation probably occurred because the molar function may be compensated by premolars (30). This hypothesis is supported by the data on masticatory efficiency, in which the coarse particle (4 mm sieve mesh) results showed a high correlation with those of masticatory performance. Results of the masticatory efficiency test for medium particles (2.8 mm sieve mesh) showed the same tendency, but represented less than 10% of masticatory efficiency within the higher dispersion, indicating an irregular comminution. The percentage of particles smaller than 2 mm was even lower, and had the lowest correlation with median particle size. Therefore, it could be considered that the artificial molar teeth are more important for comminuting smaller particles (14), being that the premolars affect mainly the medium and coarse particles (30), which have a more influence on the median particle sizes values (25).

Bite force might be another factor that contributes to chewing adaptation after loss of both the first and second molars. According to Shinogaya et al. (31), when molar occlusal surfaces are experimentally removed, bite force increases at premolars. This change could compensate for the masticatory performance in SDA subjects because of the effect on comminution capacity of premolars. This was also seen by Ikebe et al. (32), who found that the preservation of occlusal contacts of bilateral premolars was a key predictor of occlusal force. Moreover, in subjects lacking molar support, mandibular movement during mastication could be adapted to change the preferred chewing region to the premolar level (21).

Data of chewing rate showed that only the slightly SDA category showed adaptation, and the other categories revealed increased rates. Subjects without artificial first molars or premolars might have had a reduced capacity to select particles during mastication. In those cases, the lower number of Optocal particles compressed between the available occlusal surfaces might facilitate the mandibular movement to maximum intercuspal position and increase the chewing rate, probably because of a lower occlusal phase duration (33). This assumption is supported by Buschang et al. (26) and Yoshida et al. (34), who observed that subjects with a higher chewing rate had reduced masticatory performance and poorer mixing ability, respectively.

Selection chance values showed that chewing adaptation was achieved only in the slightly SDA category for particles of 8 mm. The lower selection chance in the others categories might be due to the mastication of SDA subjects during the one-chew experiment, which does not allow compensation by additional masticatory cycles, and by their lower occlusal area (29). However, as the tongue, lips and cheeks are also involved in bolus transport during chewing (24), this can provide proprioceptive information (35), explaining the adaptation to select 8 mm cubes. Probably, there is more difficulty to select particles of lower size, which could support the differences found between control and slightly SDA categories for particles of 4.8 mm and 2.4 mm. This hypothesis may be sustained by Engelen et al. (36), who determined that the perception of steel spheres sized less than 6 mm do not correlate to Optocal median particle size. Analysis of breakage function showed that adaptation was again achieved for slightly SDA condition for particles sized 8 mm and 2.4 mm. Breakage function results may be explained by the force applied to the food (27). Although bite force could be increased on the remaining teeth of the SDA subjects, the total bite force applied over dentition decrease because of the lower number of occluding teeth (32). Also, the lower number of available occlusal surfaces involves a lower number of selected particles (14, 37), consequently decreasing the possibility of breakage function adaptation in the other categories. However, due to irregular chewing, the 2.4 mm cubes could be broken before the 4.8 mm cubes in the slightly SDA category.

Chewing adaptation to SDA shown by subjects in this study could also be explained by considering the natural anterior mandibular teeth. While anterior teeth are used during initial food intake to manipulate and split the food into smaller pieces, the posterior teeth are used during rhythmical chewing when strong axial and horizontal forces are produced by the jaw muscles to grind the food (38). Periodontal afferents of teeth encode information about the direction of forces applied to individual teeth, which is important for the sensorimotor regulation of mastication (39). Since periodontal afferents of the posterior teeth are less sensitive to lower loads than afferents of the anterior teeth (40), these last teeth, in conjunction with the tongue and soft tissue (41) regulate masticatory function which may allow the adaptation of SDA subjects. In contrast, the role of artificial or natural posterior teeth is mainly mechanical (9), so the comminution capacity of the molars could be compensated for by the premolars. Furthermore, the new oral motor behaviors adopted by subjects after tooth loss could determine neuroplastic changes of the facial sensorimotor cortex, establishing adaptive events that are learned gradually (42).

Discussion about chewing adaptation should also include the role of the craniofacial morphology. Subjects with unfavorable mechanical conditions such as hyperdivergent pattern (43) probably will not be able to adapt theirs chewing to loss of teeth overloading the stomatognatic system. Then, this study may be complemented by longitudinal researches about periodontal, muscular and temporomandibular joint in order to clarify this issue. Under the terms of this study, it can be suggested that subjects adapted their chewing to a SDA up to the artificial premolars. The results can be applied to food with low or similar hardness, and similar texture to the test food used in the masticatory function analysis.

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Table 1. Optocal artificial test material components

Proportion	Material	Manufacturer
58.3%	Polydimethylsiloxane putty	Optosil Comfort, Heraeus Kulzer GmbH & Co., KG, Germany
7.5%	Toothpaste	Colgate-Palmolive, Co., Osasco, SP, Brazil
11.5%	Vaseline®	Rioquímica, São José do Rio Preto, SP, Brazil
10.2%	Dental plaster powder	Asfer, Indústria Química Ltda., São Caetano do Sul, SP, Brazil
12.5%	Alginate powder	Jeltrate, Dentsply Indústria e Comércio Ltda., Petrópolis, RJ, Brazil
20.8 mg/g	Activador universal	Optosil Xantopren, Heraeus Kulzer GmbH & Co., KG, Germany

Table 2. Masticatory performance (mm), masticatory efficiency (%), and chewing rate (cycles/min) values (mean ± SD)

	Masticatory performance	Masticatory efficiency			Chewing rate
		4 mm mesh	2.8 mm mesh	2 mm mesh	
Complete artificial teeth (control)	5.46 ± 0.64	20.43 ± 13.36	8.68 ± 6.58	3.75 ± 3.22	82.21 ± 14.68
Slightly SDA	5.51 ± 0.77	20.58 ± 15.52	8.63 ± 7.33	3.91 ± 3.93	85.38 ± 18.49
SDA	5.64 ± 0.49	16.39 ± 10.46	6.84 ± 4.77	3.10 ± 2.45	* 88.08 ± 18.03
Extremely SDA	* 6.08 ± 0.48	* 10.21 ± 9.10	* 4.29 ± 4.63	2.23 ± 2.76	* 90.22 ± 17.46
Absence of occlusal support	* 6.25 ± 0.39	* 6.95 ± 5.29	* 3.12 ± 2.75	*1.47 ± 1.64	* 89.22 ± 18.88

*Significant difference between control and dental arch categories ($p < 0.05$).

Table 3. Selection chance and breakage function values (mean ± SD) by cube size

	Selection chance			Breakage function (r)		
	8 mm	4.8 mm	2.4 mm	8 mm	4.8 mm	2.4 mm
Complete artificial teeth (control)	0.90 ± 0.16	0.41 ± 0.01	0.07 ± 0.02	0.39 ± 0.10	0.19 ± 0.08	0.05 ± 0.03
Slightly SDA	0.87 ± 0.17	* 0.34 ± 0.07	* 0.05 ± 0.01	0.39 ± 0.08	*0.15 ± 0.08	0.04 ± 0.03
SDA	* 0.65 ± 0.12	* 0.23 ± 0.07	* 0.03 ± 0.01	* 0.32 ± 0.10	*0.09 ± 0.06	*0.02 ± 0.02
Extremely SDA	* 0.45 ± 0.19	* 0.15 ± 0.06	* 0.02 ± 0.01	* 0.23 ± 0.10	*0.06 ± 0.05	*0.01 ± 0.02
Absence of occlusal support	* 0.33 ± 0.10	* 0.05 ± 0.06	* 0.00 ± 0.01	* 0.11 ± 0.10	*0.02 ± 0.03	*0.00 ± 0.00

*Significant differences between control and dental arch categories ($p < 0.05$).

CONSIDERAÇÕES GERAIS

Os resultados do primeiro capítulo descreveram como a extensão do suporte oclusal estabelecido por próteses removíveis influencia a função mastigatória. A redução imediata da performance e eficiência mastigatórias após a retirada gradual do suporte oclusal foi explicado pela alteração da capacidade de selecionar e fraturar partículas de alimento. Por sua vez, o segundo capítulo observou que cada indivíduo pôde desenvolver capacidades adaptativas à perda dentária que lhe permitiram manter uma trituração apropriada, inclusive na ausência dos segundos ou primeiros molares artificiais.

Mudanças adaptativas no sistema mastigatório necessitam de um período variável de tempo para que ocorra o aprendizado e treinamento de novas habilidades motoras eficazes que compensem a perda dentária (Avivi-Arber *et al*. 2011a). Se condições musculoesqueléticas são biomecanicamente favoráveis para resistir a uma provável sobrecarga no sistema mastigatório, e a capacidade do sistema nervoso permite o estabelecimento de mudanças neuroplásticas no córtex somatosensorial e motor (Sessle, 2011), um indivíduo poderá provavelmente se adaptar a um número menor de dentes e manter sua capacidade para triturar. São consideradas características musculoesqueléticas favoráveis padrões normodivergente ou hipodivergente (Haskell *et al*., 1986;), assim como altos valores de braços de potência dos músculos mastigatórios (van Spronsen *et al*., 1996).

Apesar dos indivíduos apresentarem ausência absoluta de suporte oclusal, suas características decorrentes dos critérios de seleção considerados no presente estudo, lhes permitiram adaptar sua função mastigatória após uma semana de redução sequencial do suporte oclusal das próteses parciais removíveis. Assim, foi observado o aumento dos valores de performance, eficiência e taxa mastigatórias, chance de seleção e função de fratura que foram imediatamente diminuídos em um primeiro momento pela remoção dos dentes artificiais. Porém, isto não necessariamente poderá acontecer em indivíduos com características fora dos critérios de seleção utilizados. Se a adaptação não acontecer harmonicamente, o sistema mastigatório será sobrecarregado articular (Amorim *et al*., 2003), muscular (Im *et al*., 2011), ou periodontalmente (Sarita *et al*., 2003), ou partículas de alimento maiores serão deglutidas diminuindo a absorção dos nutrientes ingeridos (Lemmens *et al*., 2010), assim como a saúde gastrointestinal (Carretero *et al*., 2011).

Desta forma, pode ser considerado que indivíduos com edentulismo total no maxilar superior e Classe I de Kennedy inferior, possuindo os dentes anteriores, podem ser reabilitados com próteses removíveis até pré-molares. Esta opção pode ser igualmente aplicada quando características oclusais favoráveis são adicionadas como presença de dentes naturais ântero-superiores e arco dental reduzido superior natural. Nestes casos, a propriocepção adicional determinada por estes dentes pode incrementar a esterognose oral (Avivi-Arber *et al*. 2011b) aumentando consequentemente a capacidade para selecionar e fraturar o alimento (Hirano *et al*., 2004). No caso de dentição completa em apenas um dos arcos, a reabilitação completa do arco antagonista poderia ser necessária para indivíduos com arcos dentais extremamente reduzidos (Arce-Tumbay *et al*., 2011), com a finalidade de otimizar a função mastigatória e aproveitar as superfícies oclusais naturais disponíveis. Próteses implanto-retidas ou suportadas poderiam ser consideradas como a primeira alternativa de tratamento já que tem sido observado um aumento progressivo da ósseo-percepção após sua instalação (Batista *et al.*, 2008). Entretanto, indivíduos reabilitados com prótese fixa implanto-suportada até pré-molares ou 1° molar apresentaram menor adaptação da atividade muscular durante a mastigação de alimentos de consistência dura devido ao menor incremento da atividade eletromiográfica e à redução da mesma a medida que o alimento foi triturado (Grigoriadis *et al*. 2011). Cabe mencionar que os resultados deste estudo podem ser aplicáveis a alimentos de dureza inferior ou similar, e textura semelhante ao material teste mastigável utilizado. Neste contexto, alimentos de dureza superior ao Optocal poderiam necessitar dos molares artificiais, principalmente para a trituração de partículas menores geradas pela ação prévia dos pré-molares.

Estudos controlados em indivíduos com diferentes características intra e extra-orais utilizando outros materiais testes mastigáveis de dureza conhecida são necessários com a finalidade de determinar qual seria a influência dos diferentes tratamentos protéticos na função mastigatória. Assim, poderá ser conhecido em que situações a reabilitação oral é necessária e em quais condições a capacidade adaptativa do paciente poderá ser suficiente. Este estudo analisou a influência do suporte oclusal na função mastigatória, o que deve ser complementado com estudos referentes à integridade muscular e articular, assim como coerência estética.

CONCLUSÃO

Considerando as condições nas quais este estudo foi realizado, pode ser sugerido que:

- A redução imediata da extensão do suporte oclusal de portadores de prótese parcial removível inferior de extremo livre alterou a função mastigatória, diminuindo a performance e eficiência mastigatórias devido à dificuldade para selecionar e fraturar o alimento.

- Os indivíduos do presente estudo puderam após uma semana adaptar sua função mastigatória (performance, eficiência e taxa mastigatórias, chance de seleção e função de fratura) a arcos dentais reduzidos artificiais até pré-molares.

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* De acordo com as normas da UNICAMP/FOP, baseadas na norma do International Committee of Medical Journal Editors – Grupo de Vancouver. Abreviatura dos periódicos em conformidade com o Medline.

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ANEXOS

Anexo 1. Figuras

Figura 1. Condição intra-oral dos voluntários selecionados para a pesquisa

Figura 2. Vista intra-oral dos voluntários após a reabilitação com próteses removíveis

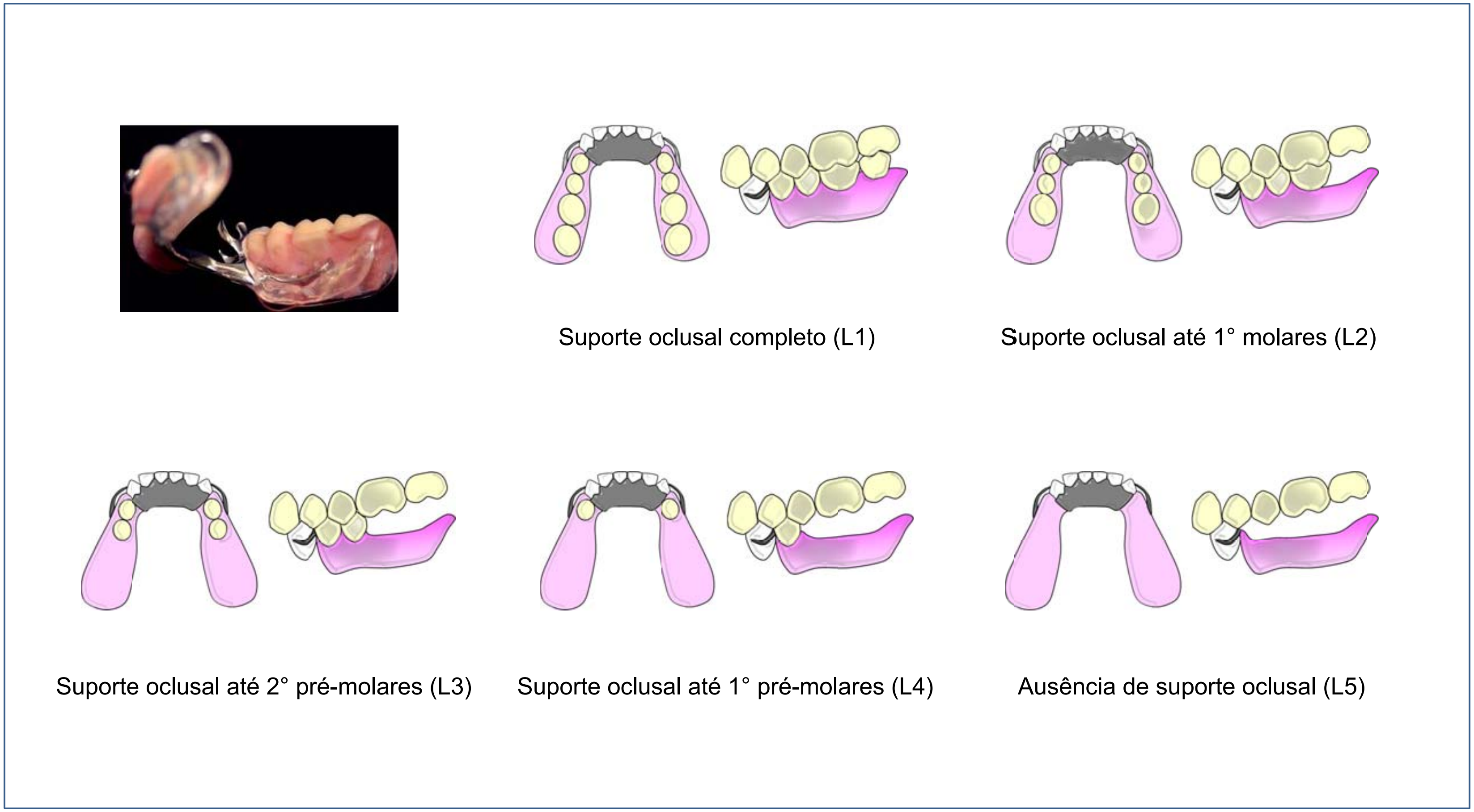

Figura 3. Esquema das vistas oclusal e lateral de cada alteração do suporte occlusal

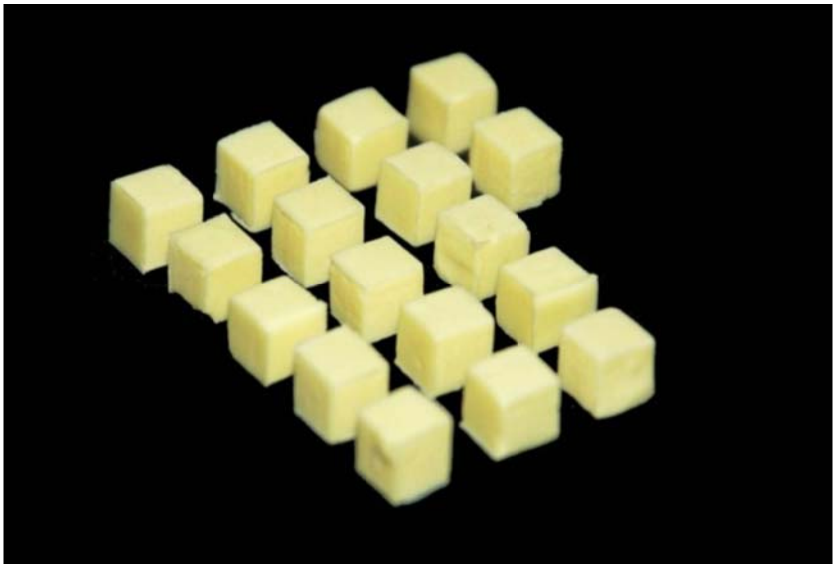

Figura 4. Cubos de Optocal de 5.6 mm de aresta utilizados para teste de performance mastigatória

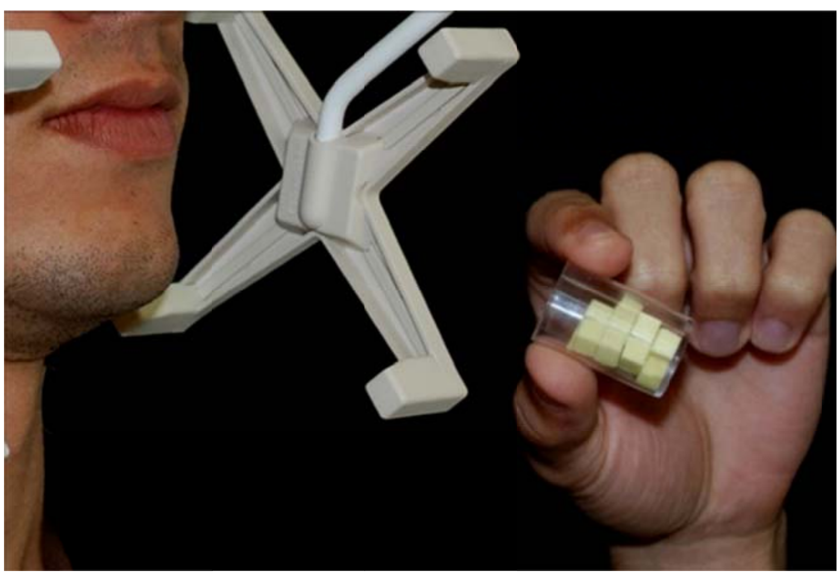

Figura 5. Posicionamento do voluntário antes de iniciar o teste de performance mastigatória e o registro cinesiográfico do padrão do ciclo mastigatório.

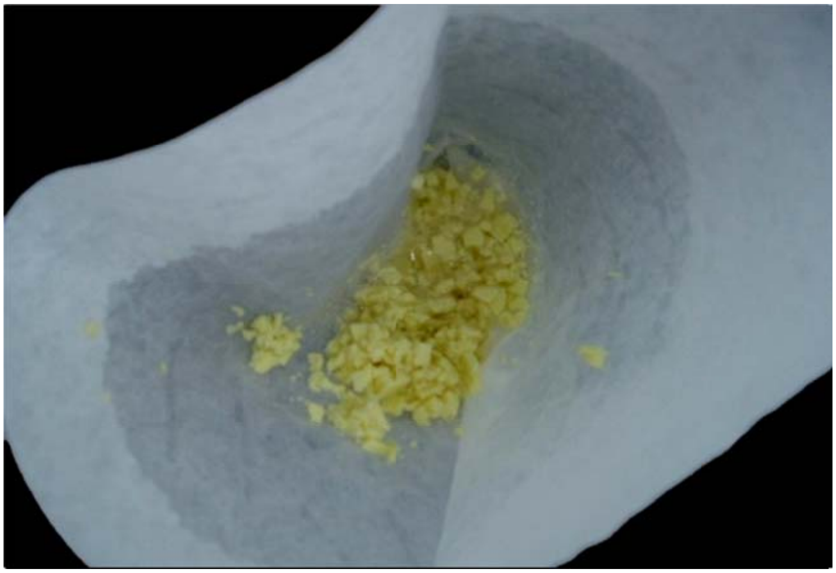

Figura 6. Optocal triturado e expectorado em filtro de papel após 20 ciclos mastigatórios

Figura 7. Sistema de fracionamento do Optocal triturado pelo método das peneiras

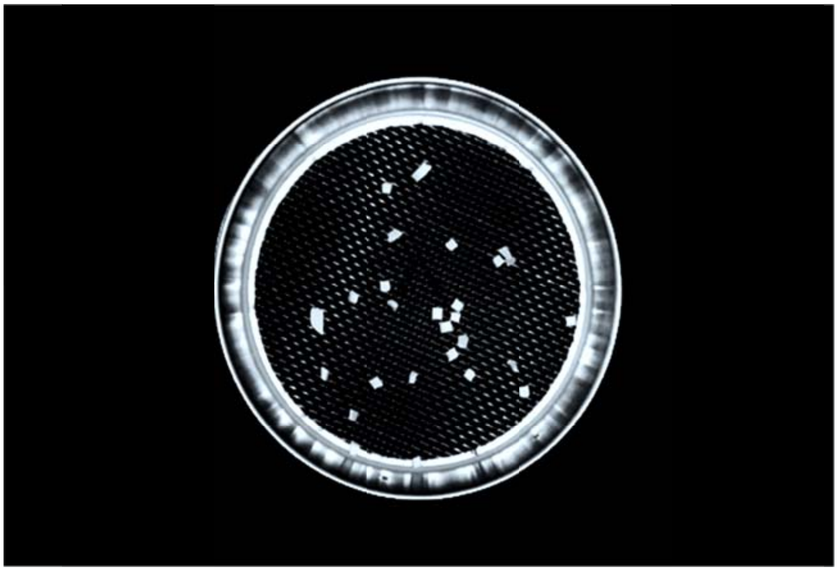

Figura 8. Exemplo de Optocal triturado retido na peneira de 5.6 mm (indicar qual é a peneira) utilizada

Figura 9. Pesagem do material retido em cada peneira

Figura 10. Cubos de Optocal utilizados nos testes de Chance de seleção e Função de fratura

Figura 11. Comparação entre os diferentes tamanhos de cubos utilizados nos testes

Figura 12. Aparência dos cubos selecionados e fraturados durante os testes de Chance de seleção e Função de fratura

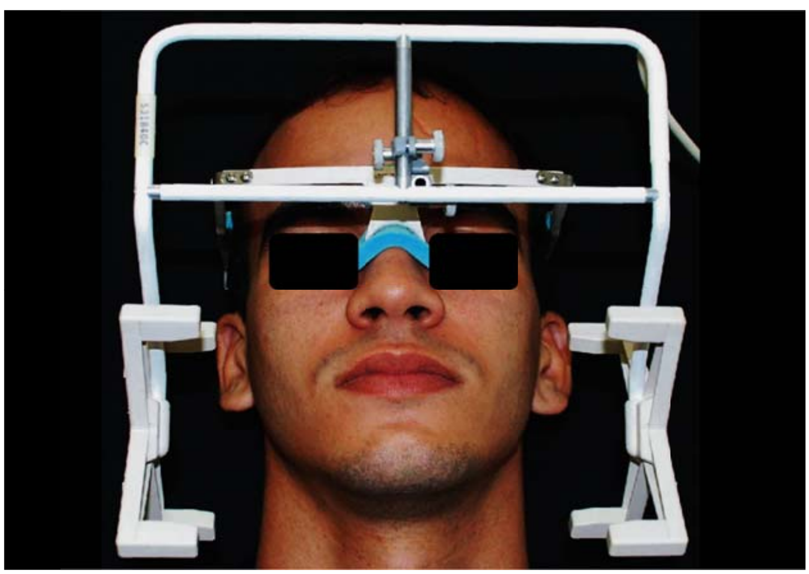

Figura 13. Posicionamento do cinesiógrafo na cabeça de um voluntário

Figura 14. Posicionamento do magneto do cinesiógrafo nos incisivos inferiores dos voluntários

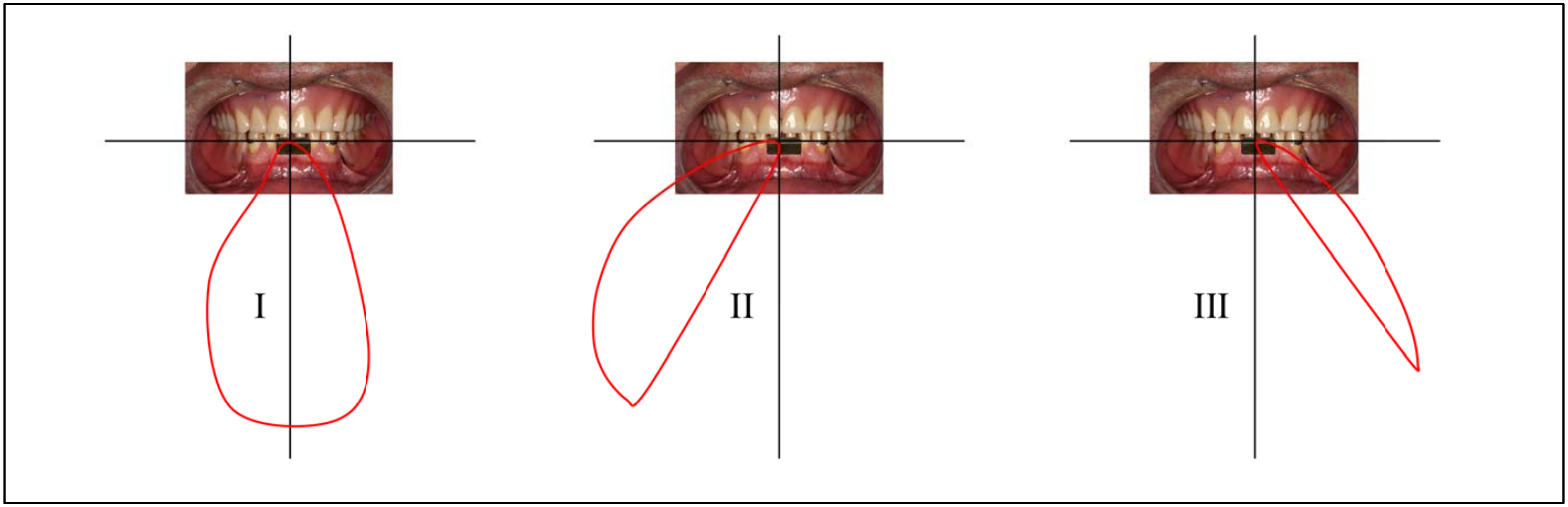

Figura 15. Padrões qualitativos de ciclo mastigatório no plano frontal

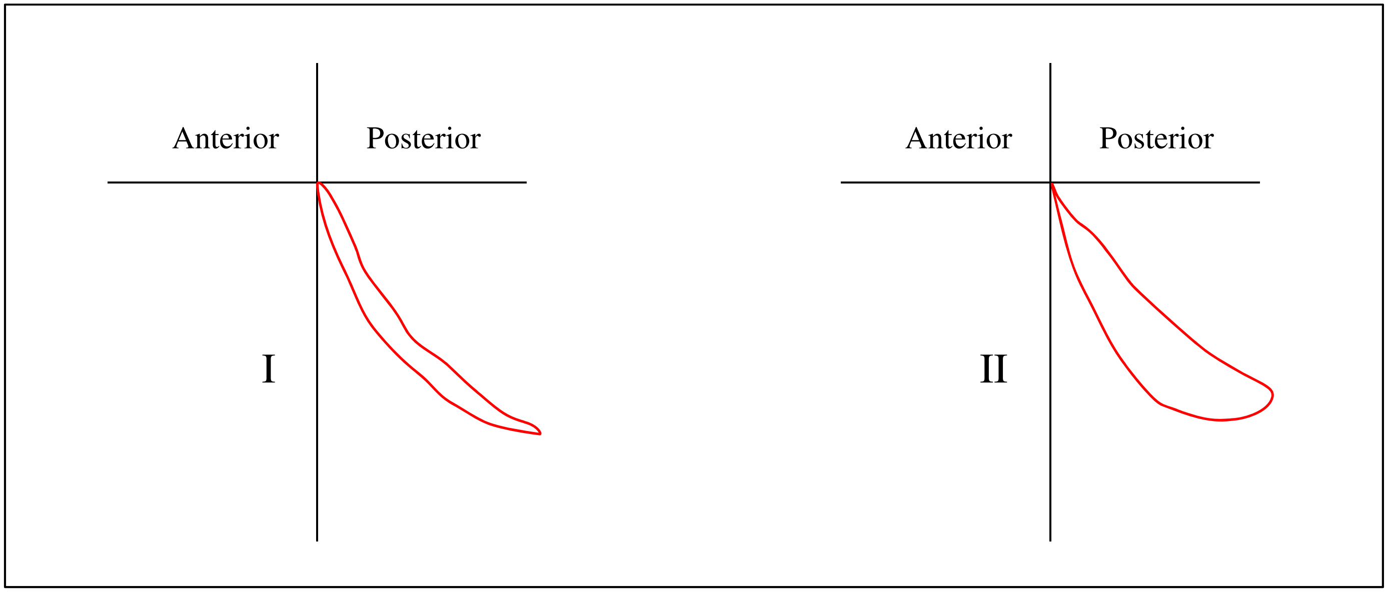

Figura 16. Padrões qualitativos de ciclo mastigatório no plano sagital

Anexo 2. Certificado de aprovação do Comitê de Ética em Pesquisa

COMITÊ DE ÉTICA EM PESQUISA
FACULDADE DE ODONTOLOGIA DE PIRACICABA
UNIVERSIDADE ESTADUAL DE CAMPINAS

CERTIFICADO

O Comitê de Ética em Pesquisa da FOP-UNICAMP certifica que o projeto de pesquisa "**Efeito da alteração do suporte oclusal na mastigação de portadores de próteses removíveis**", protocolo nº **074/2008**, dos pesquisadores **RENATA CUNHA MATHEUS RODRIGUES GARCIA e ALFONSO SáNCHEZ AYALA**, satisfaz as exigências do Conselho Nacional de Saúde – Ministério da Saúde para as pesquisas em seres humanos e foi aprovado por este comitê em 04/08/2008.

The Ethics Committee in Research of the School of Dentistry of Piracicaba - State University of Campinas, certify that the project "**Effect of occlusal support alteration on mastication of removable denture wearers**", register number **074/2008**, of **RENATA CUNHA MATHEUS RODRIGUES GARCIA and ALFONSO SáNCHEZ AYALA**, comply with the recommendations of the National Health Council – Ministry of Health of Brazil for research in human subjects and therefore was approved by this committee at 04/08/2008.

Prof. Pablo Agustin Vargas
Secretário
CEP/FOP/UNICAMP

Prof. Jacks Jorge Júnior
Coordenador
CEP/FOP/UNICAMP

Nota: O título do protocolo aparece como fornecido pelos pesquisadores, sem qualquer edição.
Notice: The title of the project appears as provided by the authors, without editing.

Anexo 3: Protocolo de submissão do artigo referente ao capítulo 1.

Manuscript title: Influence of distal occlusal support length of free-end removable partial dentures on masticatory function.

Dear Professor Rodrigues Garcia

Thank you very much for submitting the above manuscript to the International Journal of Prosthodontics. The manuscript is being evaluated and we will contact you as soon as a decision has been made.

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