Universidade Estadual de Campinas
Faculdade de Odontologia de Piracicaba

Luciano José Pereira
Cirurgião-Dentista

Avaliação morfológica, funcional e sensorial do sistema mastigatório

Tese apresentada à Faculdade de Odontologia de Piracicaba - Universidade Estadual de Campinas, para obtenção do grau de Doutor em Odontologia, área de concentração em Fisiologia Oral

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...que ser gentil é mais importante do que estar certo;

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William Shaskeapeare

SUMÁRIO

RESUMO

O objetivo do presente trabalho foi avaliar as características morfológicas, funcionais e sensoriais do sistema mastigatório de crianças, adolescentes e adultos. Na avaliação das características morfológicas as seguintes variáveis foram consideradas: espessura muscular através da ultra-sonografia, dimensões craniofaciais através de telerradiografias laterais, estágio da dentição (mista ou permanente). Na avaliação funcional as variáveis consideradas foram: sinais e sintomas de disfunção temporomandibular, força de mordida, eletromiografia dos músculos masseter e temporal e influência de fluidos adicionais na mastigação de alimentos sólidos naturais na deglutição. Na avaliação sensorial, atributos dos alimentos foram avaliados através de questionário específico. Verificou-se que a espessura dos músculos masseter e temporal anterior não se correlacionou com a atividade elétrica, entretanto as variáveis corporais peso e altura foram de influência, bem como o padrão facial. Sinais e sintomas de disfunção temporomandibular estiveram associados a uma tendência de "face longa", mas não foi possível a identificação de traço previsor de disfunção. A força de mordida aumentou da dentição mista para a permanente e a presença de sinais e sintomas de disfunção, principalmente aqueles relacionados à sensibilidade muscular, estiveram associados a uma diminuição na força de mordida no sexo feminino na dentição permanente, mas não na dentição mista. Na avaliação da mastigação, a adição de fluidos ao processo mastigatório influenciou a atividade elétrica e número de ciclos mastigatórios bem como a percepção sensorial principalmente para alimentos secos. O tipo de alimento teve maior efeito que a adição de fluidos.

ABSTRACT

The aim of this study was to evaluate the morphological, functional and sensorial characteristics of the stomatognatic system in children, adolescents and adults. To evaluate the morphology, the following variables were considered: muscle thickness using ultrasonography, craniofacial dimensions using lateral cephalograms, dentition phase (mixed and permanent dentition). Signs and symptoms of temporomandibular dysfunction, bite force, electromyography of masseter and anterior temporalis and the influence of additional fluids on the swallowing threshold were evaluated as part of the functional exams. In the sensorial evaluation, the perception of attributes during chewing of natural solid food was assessed by a specific questionnaire. It was observed that the masseter and anterior temporalis thickness was not associated to muscle activity. However, the body variables weight and height and facial morphology as well, influenced the muscle thickness. Signs and symptoms of temporomandibular dysfunction were associated to a "long face" pattern, although it was not possible to identify any predictive trace of dysfunction. Bite force increased from mixed to permanent dentition and the presence of signs and symptoms, specially those related to muscle tenderness, was correlated to a decrease in the bite force for females in the permanent dentition only. In the mastication experiments, the added fluids influenced the electrical activity and number of chewing cycles and sensorial perception as well specially for dry food. The type of food had a larger effect than the additional fluids.

INTRODUÇÃO GERAL

O estudo da fisiologia oral vem se desenvolvendo extensamente nos últimos anos. O surgimento de novos equipamentos e/ou novas metodologias tem colaborado para o melhor entendimento do funcionamento do sistema estomatognático saudável e acometido por patologias. Dentre as funções do sistema estomatognático, a mastigação se destaca por seu papel primordial na iniciação da digestão dos alimentos.

A mastigação é uma atividade rítmica controlada pelo tronco cerebral (Lund, 1991) que pode ser modificada por informações periféricas (Ottenhoff et al., 1992). O processo é iniciado pela mordida, sucedido pela mastigação propriamente dita e finalizado pela deglutição (Hiiemae et al., 1996). Durante a mastigação, os músculos elevadores da mandíbula são utilizados para sobrepujar a resistência dos alimentos (van der Bilt, 1995).

A avaliação do desempenho mastigatório pode ser realizada de diversas maneiras. A força de mordida é um dos componentes da função mastigatória e é exercida pelos músculos elevadores da mandíbula e regulada pelos sistemas nervoso, muscular, esquelético e dentário (Ow et al., 1989). A força exercida pelos músculos mastigatórios determina a quantidade de carga destinada à quebra dos alimentos e esta pode ser mensurada através de sensores específicos (Kiliaridis et al., 1993). A força de mordida varia de acordo com a estrutura facial, com a estrutura física geral e também com o gênero. Outros fatores como o estado da dentição, maloclusões, idade e sinais e sintomas de disfunção temporomandibular também são de influência (Sonnesen et al., 2001; Rentes et al., 2002; Bonjardim et al., 2005; Kamegai et al., 2005). O termo "disfunção temporomandibular" (DTM) se refere a sinais e sintomas associados à dor e distúrbios funcionais e estruturais do sistema mastigatório, especialmente a articulação temporomandibular (ATM) e músculos (Sonnesen et al., 2001). A mensuração da força de mordida tem valor clínico, uma vez que pode ser utilizada no entendimento da função mastigatória de indivíduos saudáveis e de pacientes com disfunções do sistema estomatognático e outras patologias relacionadas (Kobayashi et al., 1993; Kim e Oh, 1997).

A força de mordida produzida durante contração isométrica máxima é resultante da ação conjunta de pelo menos seis músculos elevadores da mandíbula. A avaliação da contribuição individual de cada músculo, portanto, não pode ser obtida pela mensuração da força total. A atividade individual dos músculos elevadores da mandíbula conseqüentemente tem sido avaliada através de estudos eletromiográficos (EMG), realizados pelo uso de eletrodos de superfície (van der Glas et al., 1996; Scopel et al., 2005) e utilizada como exame complementar, principalmente no diagnóstico das disfunções, bem como na avaliação de tratamentos instituídos, mostrando-se um método confiável e reprodutível (Castroflorio et al., 2005). Estudos sugerem que a atividade elétrica dos músculos mastigatórios em pacientes portadores de DTM apresenta-se aumentada no estado de repouso (Rodrigues et al., 2004) e diminuída em máxima contração voluntária (Dahlstrom e Haraldson 1989). Diferenças na espessura do tecido adiposo subcutâneo podem modificar a impedância da pele e também podem gerar variação adicional entre indivíduos, bem como diferenças no padrão mastigatório (Mioche et. al., 1999).

A atividade elétrica dos músculos mastigatórios também pode ser influenciada pela textura dos alimentos. A informação proprioceptiva da atividade elétrica muscular está relacionada com a percepção de textura (Mathevon et al., 1995; Mioche e Martin, 1998). Em outras palavras, durante a mastigação, a atividade dos músculos masseter e temporal aumentam de acordo com o aumento da resistência do alimento (Mioche et al., 1999).

A anatomia e função dos músculos mastigatórios podem também ser avaliadas através de ultra-sonografia (Bertram et al., 2003; Ariji et al., 2004). A técnica de realização é considerada de grande valia quando comparada a outras técnicas invasivas e com efeitos cumulativos, como a tomografia computadorizada e a ressonância magnética, além de proporcionar uma diminuição considerável nos custos dos exames (Emshoff et al., 1999). Conseqüentemente, a ultra-sonografia é um método que permite a mensuração da espessura dos músculos masseter e temporal anterior, bem como de outros músculos superficiais (Ariji et al., 2004).

A espessura muscular, força de mordida e morfologia facial estão relacionadas. Van Spronsen et al. (1989) encontraram que a espessura do músculo masseter mensurada tanto por tomografia computadorizada quanto por ressonância magnética, se correlacionou significativamente com a força de mordida. Para o músculo temporal, somente por ressonância magnética houve correlação entre espessura e força de mordida. Sonnensen et al. (2001) demonstraram que a magnitude da força de mordida estava negativamente correlacionada com padrão facial vertical. Com relação a sinais e sintomas de DTM, pouco se sabe sobre sua influência no padrão de crescimento craniofacial bem como sua influência no desenvolvimento da musculatura mastigatória. Entretanto, é relatada na literatura certa tendência à associação de padrões faciais verticais e sensibilidade muscular (Sonnesen et al., 2001). Entretanto, as correlações entre padrão facial e sinais e sintomas de DTM apresentam-se leves a moderadas, não permitindo a determinação de um tipo facial característico ou previsor de disfunção.

A mastigação também é influenciada por fatores fisiológicos relacionados à quantidade de saliva e fatores relacionados às propriedades dos alimentos como a porcentagem de gordura, água, textura, volume (Gavião et al., 2004). Além disso, a percepção desses atributos pelo indivíduo, também parece ser de importância para o desencadeamento do processo de deglutição (Prinz e Lucas, 1995). A água presente na saliva umedece o alimento, enquanto as mucinas aderem-se nas partículas mastigadas formando um bolo alimentar facilitando a deglutição

(Pesdersen et al., 2002). O momento da deglutição tem se mostrado constante para um mesmo indivíduo, quando o mesmo tipo de alimento é oferecido repetidamente, apesar de o número de ciclos mastigatórios variar enormemente entre indivíduos diferentes (Fontijn-Tekamp et al., 2004). Aparentemente, cada indivíduo está acostumado a mastigar o alimento por um certo período de tempo antes de deglutí-lo (Engelen et al., 2005).

Assumindo-se que indivíduos normais estão acostumados com o volume de saliva presente na boca durante a mastigação, supõe-se que os sistemas sensoriais estão calibrados de acordo com o volume de saliva produzido por este indivíduo (Engelen et al., 2003). Desta forma, pode-se criar a hipótese de que o aumento artificial do volume de saliva juntamente com a presença do alimento durante a mastigação pode alterar a percepção do mesmo. A razão para isso está no fato de que qualquer aumento no volume de saliva poderia interferir no equilíbrio do sistema mastigatório.

O presente estudo versa sobre a avaliação do sistema estomatognático em indivíduos saudáveis e portadores de sinais e sintomas de disfunção temporomandibular, bem como avaliação objetiva e sensorial da função mastigatória.

PROPOSIÇÃO

O objetivo do presente trabalho foi avaliar as características morfológicas e funcionais e sensoriais do sistema mastigatório de crianças, adolescentes e adultos. Na avaliação das características morfológicas as seguintes variáveis foram consideradas: espessura muscular através da ultra-sonografia, dimensões craniofaciais através de telerradiografias laterais, estágio da dentição (mista ou permanente). Na avaliação funcional as variáveis consideradas foram: sinais e sintomas de disfunção temporomandibular, força de mordida, eletromiografia dos músculos masseter e temporal, e influência dos alimentos na mastigação e deglutição. Para tal objetivo, o trabalho foi dividido em seis capítulos:

Capítulo 1- "Ultrasonography and electromyography of masticatory muscles in a group of adolescents with signs and symptoms of TMD".

Capítulo 2- "Muscle thickness, bite force and craniofacial dimensions in adolescents with signs and symptoms of temporomandibular dysfunction."

Capítulo 3- "Bite force and its correlation with clinical signs of temporomandibular dysfunction in the mixed and permanent dentition."

Capítulo 4- "Mastication: influence of saliva, food, dentition, muscle force and temporomandibular disorders - *Review Article.*"

Capítulo 5- "Effects of added fluids on chewing and swallowing."

Capítulo 6- "Effects of added fluids in the perception of natural solid food."

O presente estudo foi realizado em formato alternativo, conforme deliberação da Comissão Central de Pós-graduação (CCPG) da Universidade Estadual de Campinas (UNICAMP) nº 001/98.

ULTRASONOGRAPHY AND ELECTROMYOGRAPHY OF MASTICATORY MUSCLES IN A GROUP OF ADOLESCENTS WITH SIGNS AND SYMPTOMS OF TMD

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Ultrasonography and electromyography of masticatory muscles in a group of adolescents with signs and symptoms of TMD

ABSTRACT

The thickness and electrical activity of masseter and anterior temporalis muscles were compared in adolescents with and without signs and symptoms of TMD. Forty individuals were selected using the CranioMandibular Index and a questionnaire. There was no significant correlation between thickness and activity ($p>0.05$). However, there were correlations between thickness and weight and height ($p<0.05$). The effect of signs and symptoms on muscle thickness and activity was weak, considering the low CMI scores found.

INTRODUCTION

The term "temporomandibular dysfunction" (TMD) refers to signs and symptoms associated with pain and functional and structural disturbances of the masticatory system, especially the temporomandibular joints and the masticatory muscles.[1] According to the literature, muscle hyperactivity is the most common etiological factor in myogenic TMD and this can contribute to internal derangement in the temporomandibular joint. [2-6]

The field of medical imaging, stimulated by advances in digital and communication technologies, has expanded greatly. New imaging techniques that reveal greater anatomical detail are available in most diagnostic departments and among these, ultrasonographic imaging (US) analysis of the orofacial musculature is included.[7, 8] In several studies, ultrasonography has been advocated for measuring muscle cross-sections and to correlate the findings with those of temporomandibular dysfunction, muscle palpation pain, facial morphology, bite force and occlusal factors.[9-11]

Analyses of surface recorded electromyography (EMG) amplitudes versus force have been used to study muscular performance in terms of recruitment and motor unit firing frequencies.[12, 13] Nevertheless, there are few studies concerning the correlation between muscle function and thickness, particularly in the masticatory muscles. In addition, the correlation between 'height' and 'weight' on the one hand and 'muscle thickness' on the other, in subjects with signs and symptoms of TMD is still not well studied, though these variables seem to influence muscle thickness.[14] Previous studies had found a significant correlation between thickness and activity for the masseter muscle in adults[9] and for Class I children for the anterior temporalis.[14] Conversely, studies dealing with adolescents with signs and symptoms of TMD are rare.

Therefore, the purpose of the present study was to compare the thickness and electrical activity of the masseter and anterior temporalis amongst adolescents, with and without signs and symptoms of TMD, and also to evaluate the relationship between muscle thickness, body weight and height.

MATERIAL AND METHODS

Two hundred and seventeen adolescents (120 girls/97 boys), aged 12 to 18 years were examined in public schools in the city of Piracicaba/Brazil, and 40 were selected, taking into account the presence and absence of signs and symptoms of TMD. The Ethics Committee of Piracicaba Dental School approved the research and parental and adolescents consent was obtained. Those who received any type of orthodontic treatment prior to or during the research examination period were excluded from the study.

TMD signs were assessed by calculating the CranioMandibular Index (CMI), as described by Fricton and Schiffman.[15] This was carried out by two calibrated examiners (Kappa=0.936). The CMI has a 0 to 1 scale that measures tenderness and dysfunction in the stomatognathic system and includes all currently recognized signs of TMJ disorders.[15, 16] There are 2 subscales: the Dysfunction Index (DI) and the Palpation Index (PI). The DI is designed to evaluate limitation in mandibular movement, pain and deviation in movement, TMJ noise, and TMJ tenderness. The PI evaluates the presence of muscle tenderness in the stomatognathic system. Thus, the CMI distinguishes joint problems from muscle problems.

A self-report questionnaire was used to assess the presence of subjective symptoms according to Riolo *et al.*, [17] regarding pain in the jaws when functioning (e.g. chewing), unusually frequent headaches (more than once a week), stiffness/tiredness in the jaws, difficulty in opening the mouth wide, grinding teeth, and sounds in the TMJs. Each question could be answered with "yes" or "no".

Considering severity of clinical signs according to CMI, i.e., the lowest and the highest scores, the forty selected adolescents were distributed, respectively, in two groups: Control Group (10 boys/10 girls, mean age 14.3±2.2 and 13.7±1.8 years) and the group with signs and symptoms of TMD (SSTMD Group, 10 boys/10 girls, mean age 14.0±1.8 and 13.5±2.4 years). To be included in SSTMD Group, the subjects had to have at least one symptom of the condition based on the questionnaire.[17] There were significant statistical difference between group scores for DI, PI and CMI ($p<0.05$). US and EMG were performed in both groups.

Ultrasonography

The masseter and anterior temporalis evaluation was conducted using the Just-Vision 200 digital ultrasonography system (Toshiba Corporation, Japan) and the images were obtained with a high-resolution real-time 56mm/10-MHz linear-array transducer. All subjects were examined by one trained examiner, who had no information regarding symptoms or CMI scores. The transducer was positioned against the surface of the skin over the central portion of the masseter muscle (the area of greatest lateral distention) and for anterior temporalis it was placed just in front of the anterior border of the hair line (the area of greatest lateral distention).[14, 18] The transducer was gradually shifted to obtain optimal visualization. The distance was measured directly on the screen. The measurements were recorded immediately both in the relaxed and clenched states of the jaws. The scanning was performed twice for each site and the means were used for statistical analysis.

Measurement error for ultrasound

The errors of measurement (Se) for the thickness of masticatory muscles were assessed from repeated measurements on two separate occasions (m1, m2) of 20 randomly selected subjects (n), using the Dahlberg's formula: Se =$\sqrt{\Sigma (m1 - m2)2 / 2n}$. The error was 0.47 mm for the contracted and 0.26 mm for the relaxed masseter and 0.32 mm for the contracted and 0.29 mm for the relaxed anterior temporalis.

Electromyography

Muscle activities were measured with the EMG system (São Paulo/Brazil) MCS-V2 Electromyograph and passive silver-chloride surface electrodes (Tyco Healthcare – Kendall LTP/Canada). The electrodes were placed at the same sites as for the masseter and anterior temporalis ultrasonography recordings. The reference electrode was placed on the right fist. In order to minimize contact impedance, the recording sites were cleaned with a piece of cotton soaked with 70% alcohol.[19] The electrodes were held in position using Elastoplast. The muscle activity was recorded twice when the subjects clenched their teeth (maximum voluntary clench) while using the material *Parafilm* on their occlusal surfaces. The means of RMS in both trials were used. The methodology for signal treatment was in accordance with Merletti.[20]

Body measurements

Body measurements consisted of height (m) and weight (kg). Height was measured with participants standing with their backs and heels against a wall, to which a stadiometer was fixed. The individuals were asked to look straight ahead and to stretch as much as possible, but to keep their heels on the floor. A survey table was let down onto the head and the height was recorded to the nearest 1 mm. Body weight was measured using an anthropometric scale, with all the subjects bare-footed, and recorded to the nearest 0.5 kg.

Statistical Methods

The normality of the distributions was assessed by the Shapiro-Wilks *W*-test, showing that the DI, PI and CMI scores and the electromyography data were not normally distributed in the two groups. The electromyography data for both groups and CMI and subscales for SSTMD group were log10 transformed to more closely approximate normality. It was not possible to transform CMI and subscales for the Control Group, thus the Mann-Whitney was used to compare the scores between and within groups. Muscle thickness among groups, genders and data from the relaxed to contracted states, as well as the comparisons of the electromyography data were evaluated by ANOVA. Spearman rank correlation analysis was used to evaluate the relationship between muscle thickness, activity and DI, PI, and CMI in the Control Group, and Pearson correlation analysis in the SSTMD Group, due to the normality of the samples, considering the contracted state data. The correlations between muscle thickness and body variables were assessed by Pearson's correlation test. The non-paired "*t*" test was performed to compare body weight and height in both groups.

RESULTS

The descriptive statistics for weight, height, muscle thickness and activity (RMS) are expressed in Table 1, which also includes the values for the CMI, DI and PI for both groups. Table 2 shows the frequency of subjective symptoms in the SSTMD group individuals, since the Control group was free of subjective symptoms. There was significant difference for CMI values between groups ($p<0.05$) and in the SSSTMD group, girls presented higher values than boys ($p<0.05$). Values of body variables were not statistically different between groups and genders ($p>0.05$).

The ultrasonographic evaluation determined that thickness increased significantly from the relaxed to the maximally contracted state ($p<0.01$). On the scan, this change was directly visible, as the muscle bulged during contraction and the septa curled. The comparison of muscle thickness between groups was not significant ($p>0.05$), which means that subjects in the SSTMD group presented the same range of muscle thickness than the matched Controls. In relation to gender, only the anterior temporalis of boys from control group was significantly thicker than that of girls in the same group ($p<0.05$). The relaxed and contracted thickness and EMG values were not different between right and left sides for massseter and anterior temporalis in both groups ($p>0.05$), thus right and left sides were pooled for statistical analysis. Besides, there was no significant difference for EMG activity between groups ($p>0.05$). The correlations among CMI and subscales, muscle thickness and activity were not significant in Control group ($p>0.05$). However, in the SSTMD group, contracted masseter correlated negatively with CMI ($r= -0.534$, $p= 0.015$). The correlations were not significant between muscle thickness and activity, as presented in Table 3. On the other hand, muscle thickness and body variables were significantly correlated (Table 4).

DISCUSSION

The present study evaluated the relationship between masticatory muscle variables in adolescents with and without signs and symptoms of temporomandibular dysfunction. The decision to implement a dysfunction index, specifically the CMI, was based on the possibility of being able to measure the severity of problems objectively, using clearly defined criteria, simple clinical methods and easy scoring. In addition, this index had a good intra and inter-examiner correlation.[15, 21] The CMI index has established validity and reliability.[15,16] Recently, the operational definitions for CMI were redesigned to conform precisely to those of the RDC/TMD, resulting in a clinical evaluation protocol – the Temporomandibular Index (TMI). Ideally, criterion validity would be measured relative to a "gold standard".[21] As no such standard exists for TMD, criterion validity of a new index requires its comparison to an accepted index that measures the same construction. Since the CMI has been used and validated repeatedly in clinical studies, the TMI was compared to it. Criterion validity of the TMI and CMI showed excellent agreement (0.97). Because the CMI/TMI instruments include almost the same examination items as the RDC/TMD, the diagnostic outcomes are expected to be similar to that of RDC/TMD. [21]

The symptom questionnaire showed itself to be a simple and suitable tool, easily understood by the volunteers, thus allowing less examiner influence on the individuals and their answers. The most prevalent symptom in the SSTMD group was joint noises (Table 2). The application of an anamnestic questionnaire for detecting TMD symptoms has the advantage of being easily used by general practitioners or epidemiologists. Although, it has been proved to be a useful tool, in a complete clinical examination it is always mandatory to confirm subjective findings.[22]

The CMI scores obtained were lower than those presented by others, [15, 16] probably due to the fact that this sample was comprised of non-patient adolescents, as the study was carried out in a general/randomized population and not among people seeking treatment. Several studies have reported that severe dysfunction at a young age is rare, supporting the results presented. [23, 24] The girls selected for the SSTMD group presented significantly higher scores for CMI than boys in the same group, suggesting that girls were more affected than boys. These results may provide some evidence of gender differences in pain perception, as women have reported more clinical pain, lower pain threshold and tolerance levels than men and are vulnerable to the development and maintenance of musculoskeletal pain conditions. [25]

The anatomy and function of the human masticatory muscles have already been examined by US and EMG, [8, 26, 27] which makes their application useful for evaluating the masseter and anterior temporalis in adolescents with signs and symptoms of TMD. The US technique is considered to be uncomplicated, and represents a considerable improvement compared to conventional methods for assessing masticatory muscles thickness.[28] Moreover, understanding muscular activity (EMG) related to the dysfunction, is an important resource to help with differential diagnosis and supplies substantial data for the survey and management of the suggested therapy.[27] Computed tomography (CT) and magnetic resonance imaging (MRI) are also used for evaluating cross-sectional areas. However, both techniques have disadvantages related to cumulative biological effects and clinical availability and cost. [29, 30]

The current research showed that muscle area increased significantly from the relaxed to the maximally contracted states, as also verified by others, [9, 28, 29] which is predictable, despite the muscle shortening during contraction. Both contracted and relaxed muscle thicknesses were measured, because in the literature the relaxed muscle thickness has been considered less accurate, owing to higher susceptibility to the pressure with which the transducer is placed on the cheek. [31, 32]

There was no correlation between the US and EMG data in the two groups, which could be attributed to the evaluation in contracted state. It is possible that this position does not always coincide with maximum muscle activation, and therefore, in some cases, the muscle thickness measurements might not be indicative of the true contraction potential of the muscles. There are few studies regarding the correlation between these variables in the masticatory musculature, mainly in presence of signs and symptoms of TMD, consequently it is difficult to compare and to draw definitive conclusions about this finding. However, in adults without signs and symptoms, a connection was observed between masseter thickness measurements and muscle function.[9] In children with class I molar occlusion having normal anterior relationship, there was a significant correlation between thickness and activity in the anterior temporalis muscle, but it was also considered premature to give a final verdict based on this result, since it was a pioneering study.[14] Nevertheless, similar absence of correlation between muscle thickness and EMG was found for the *obliquus externus* muscle in subjects with and without low back pain.[33] Differences in sample composition and subjects variations in age and occlusion are possibly the cause of the differing outcomes.

The extent of occlusal contacts affects the electric activity and a reduction in the number of occlusal contacts might result in insufficient masticatory muscle strength development,[34] which could explain the variability in the EMG signal achievement, in spite of the number of occlusal contacts not being taken into account in the methodology used in this study. On the other hand, the thickness and composition of the cutaneous and subcutaneous tissues overlying the masticatory muscles are made of connective tissue and fat, which are low-pass filters.[19] Thus, changes in the composition of EMG frequency and amplitude of the EMG signal during maximal voluntary contraction are likely to be attenuated. Hence, a systematic difference between the various subject groups, with regard to the thickness of the soft tissues covering the muscle may, at least in part, be an explanation for the differences in mean levels of jaw-elevator muscle activity among groups or subjects.

The mean muscle thickness values found for both groups (Table 1) were in agreement with the literature.[9, 31, 32, 37-39] There was no difference for muscle thickness between the two groups, probably due to the sample age and because the signs and symptoms of TMD, even when present, tended to be mild to moderate, and this might be not enough for an alteration in muscle size. Gender differences in muscles thickness were also not significant, except for the anterior temporalis in the Control group, but this difference could be explained by masticatory side preferences and/or the fact that in the absence of pain, boys tend to have thicker muscles than girls.[39] On the other hand, the pubertal stage can also influence the muscle size and these data were not evaluated in this study. The increase in muscle mass during puberty may be influenced by androgenic steroids creating the difference between male and female muscle strength. [40]

There were no significant correlations among CMI and subscales and muscle thickness and activity in the Control group. But in the SSTMD group there was a significant negative correlation between masseter thickness and CMI, which could suggest that, as the signs and symptoms increase, the masseter thickness decreases, probably due to masticatory function impairment. However, it has already been stated that an ultrasonographic feature of the masseter muscle would be an increase in muscle thickness in patients with TMD.[8] The cause or mechanism of thickening is not well defined. The masseter muscle thickness measured by US decreased after stabilization-type splint therapy in patients with TMD, although no significant difference was found between values before and after treatment.[10] It was suggested that the cause of muscle thickening would be an edematous change in the muscle.[41, 42] Based on these observations, long-term low-level contraction, which is suggested to be caused by psychological stress or prolonged work, may be related to edematous muscle thickening. The increased thickness in patients who have suffered from muscle pain for a relatively long time would be related to muscle edema.[8] In the present sample, only the presence of signs and symptoms of TMD were stated and consequently, the level of dysfunction was probably not enough to cause muscle edema.

There were significant correlations among thickness and weight and height of the masseter and anterior temporalis in the two groups, in agreement to Kiliaridis and Kalebo[31] and Raadsheer *et al.*, [39] who found significant correlation only between muscle thickness and weight. Lack of some of the correlations for weight and function and muscle thickness could be related to facial morphology, as has already been found in other studies.[9, 43] The interaction between muscle thickness and facial morphology in individuals with signs and symptoms of TMD are also of interest and these data were obtained in the present sample and will form the basis of another report. Other factors, such as occlusion, preference of masticatory side, feeding behavior, and parafunctional habits are also of interest and further studies in this field are encouraged. Furthermore, epidemiologic evaluations and follow-up studies concerning young individuals are rare.

CONCLUSIONS

It was concluded that in the sample studied there was no correlation between masticatory muscle thickness and electrical activity. However, there were significant correlations between muscle thickness and body variables, mainly in the Control subjects, indicating that masticatory muscle thickness follows the general body development in normal conditions. The effect of signs and symptoms of TMD on the muscle thickness and activity of adolescents was weak, considering the low CMI scores found.

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Table 1. Craniomandibular Index (CMI), Palpation Index (PI), Dysfuntion Index (DI) , muscle thickness (mm) and root mean square (RMS) (uVs) in Control and SSTMD groups.

Control group											
	Weight(Kg)	Height (m)	DI*	PI*	CMI*	MR**	MC**	TR**	TC**	EMG M	EMG T
Median	52.75	1.63	0.07	0	0.04	10.15	13.32	3.05	4.47	24.51	33.53
Mean	53.41	1.62	0.06	0.01	0.03	10.00	13.30	2.96	4.50	33.81	60.87
SD	9.91	0.09	0.03	0.02	0.01	0.86	1.27	0.53	0.79	30.25	72.50
SEM	2.22	0.02	0.01	0	0.00	0.19	0.28	0.12	0.17	6.76	16.21
SSTMD group											
Median	50.15	1.62	0.14	0.31	0.23	10.15	12.52	2.80	4.20	14.69	39.09
Mean	53.88	1.59	0.16	0.31	0.23	10.55	13.31	2.89	4.21	27.05	66.49
SD	14.25	0.12	0.10	0.17	0.09	1.50	2.05	0.42	0.66	26.98	72.81
SEM	3.19	0.03	0.02	0.04	0.02	0.33	0.45	0.01	0.14	6.03	16.28

MR: masseter relaxed; MC: masseter clenching; TR: anterior temporalis relaxed; TC: anterior temporalis clenching; EMG M: activity masseter; EMG T: activity anterior temporalis

*$p<0.05$ between groups in the same column

**$p<0.05$ between relaxed to contracted state for muscle thickness inside the groups

Table 2. Subjective symptoms occurrence in SSTMD group

Symptoms	Nº of positive answers
Pain or tiredness in the jaws/face	9
Problem in open mouth wide	4
Joint sounds	13
Grinding teeth	7
Headache	8

Table 3. Correlation coefficients and p values for muscle thickness (contracted state) and activity in the Control and SSTMD groups

		Masseter	Anterior Temporalis
Control	R	0.05	0.06
	p	0.83	0.80
SSTMD	R	0.21	0.11
	p	0.37	0.65

p>0.05 all correlations were not significant

Table 4. Correlation coefficients and p values for muscle thickness and weight and height in Control and SSTMD groups

			Masseter		Anterior Temporalis	
			MR	MC	TR	TC
Control	weight	R	0.69*	0.38	-0.70*	-0.58*
		p	0.00	0.10	0.00	0.01
	height	R	0.70*	0.46*	-0.50*	-0.49*
		p	0.00	0.04	0.02	0.03
SSTMD	weight	R	0.58*	0.64*	0.42	0.30
		p	0.00	0.00	0.06	0.19
	height	R	0.65*	0.70*	0.29	0.28
		p	0.00	0.00	0.22	0.24

*$p<0.05$

Muscle thickness, bite force and craniofacial dimensions in adolescents with signs and symptoms of temporomandibular dysfunction

Running title: TMD, craniofacial dimensions and muscle thickness

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Muscle thickness, bite force and craniofacial dimensions in adolescents with signs and symptoms of temporomandibular dysfunction

Summary

Ultrasonography has been used to associate muscle thickness, temporomandibular disorders (TMD), facial morphology and bite force. The aim of this study was to evaluate signs and symptoms of TMD (CraniomandibularIndex - CMI), masseter and anterior temporalis thickness, facial dimensions and bite force in adolescents: 20 with signs and symptoms (SSTMD) and 20 without (Control). Ultrasonography was conducted using Just-Vision 200 and bite force using a pressure transducer. Measurements on cephalograms: anterior (n-gn, n-me, sp-gn) and posterior facial dimensions (S-tgo), jaw inclination (NSL/ML), vertical jaw relationship (NL/ML), gonial angle (ML/RL), overbite and overjet. We analysed the data with analysis of variance, Pearson's and Spearman's Correlation and multiple regression. The SSTMD group showed smaller bite force than controls ($p < 0.05$). In the control group, bite force was negatively correlated to jaw inclination and overbite. There were negative correlations between anterior temporalis thickness and anterior facial dimensions; and positive correlations for masseter and anterior temporalis and posterior dimensions. In the SSTMD group there were positive correlations for masseter and bite force, anterior and posterior dimensions. Negative correlations were found for masseter and temporalis and jaw inclination and vertical jaw relationship. Multiple regression showed that in the control group the overjet and jaw inclination contributed for 50% to the bite force variance. In the SSTMD group, the contracted masseter contributed for 39%. The correlations between CMI and the craniofacial variables were more significant in the SSTMD group. In conclusion, muscle thickness influenced facial dimensions and bite force in adolescents with signs and symptoms of TMD.

Introduction

The term "temporomandibular dysfunction" (TMD) refers to symptoms and signs associated with pain and functional and structural disturbances of the masticatory system, especially the temporomandibular joints and the masticatory muscles (Sonnesen *et al*., 2001).

Ultrasonography has been used for the measurement of the masticatory muscle thickness in experimental and clinical studies (Emshoff and Bertram, 1998; Bertram *et al*., 2001) and it was confirmed to be a reliable procedure. It can depict the thickness of the masseter and temporalis muscles situated superficial to the bone structures.

Changes in size and shape of the bony components of the craniofacial skeleton during growth and their influence on the masticatory system have been extensively studied. Many investigators have shown a significant interaction between jaw muscle function and facial morphology (Bakke and Michler, 1991; Raadsheer *et al*., 1996; Raadsheer *et al*., 1999; Sonnesen *et al*., 2001). The potential influence of bite force on the development of the masticatory function has also been reported (Braun *et al*., 1995). Moreover, previous studies have found that low maximal mandibular elevator muscle activity or low bite force are associated with a vertical facial morphology (Raadsheer *et al*., 1999) and these characteristics are often seen in patients with symptoms and signs of TMD (Kroon and Naeije, 1992).

Although there have been many studies regarding the use of ultrasonography for evaluating the masticatory muscles in healthy volunteers (Raadsheer *et al*., 1996; Kubota *et al*., 1998) and patients with inflammation (Ariji *et al*., 2001), the features are not well documented in patients with TMD (Ariji *et al*., 2004) and especially in young subjects with signs and symptoms.

Therefore, the aim of the present study was to examine whether any consistent pattern of associations could be found between the occurrence of symptoms and signs of TMD, craniofacial dimensions, muscle thickness and bite force in a group of adolescents.

Material and methods

Subjects aged 12-18 years were selected from public schools in the city of Piracicaba (Brazil). The Ethics Committee of Piracicaba Dental School approved the research. Adolescents who received any type of orthodontic treatment prior to or during the research examination period were excluded from the study. Six hundred written consents were distributed and parental and adolescent's consents were obtained from 217 subjects (120 girls/97 boys). Initially, possible TMD signs were assessed by calculating the CranioMandibular Index (CMI), as described by Fricton and Schiffman (1986). This was carried out by two calibrated examiners (Kappa=0.94). The CMI has a 0 to 1 scale that measures tenderness and dysfunction in the stomatognathic system and includes all currently recognized signs of TMJ disorders (Fricton and Schiffman 1986; 1987). There are 2 subscales: the Dysfunction Index (DI) and the Palpation Index (PI). The DI is designed to evaluate limitation in mandibular movement, pain and deviation in movement, TMJ sound, and TMJ tenderness. The PI evaluates the presence of muscle tenderness in the stomatognathic system. Thus, the CMI distinguishes joint problems from muscle problems.

A self-report questionnaire was used to assess the presence of subjective symptoms according to Riolo *et al*. (1987) regarding pain in the jaws when functioning (e.g. chewing), unusually frequent headaches (more than once a week), stiffness/tiredness in the jaws, difficulty in opening the mouth wide, grinding teeth, and sounds in the TMJs. Each question could be answered with "yes" or "no".

Forty adolescents out of the 217 subjects were selected to dichotomize the data in order to compare "extreme" groups, and the lower and upper extremity values were used to integrate the Control group (10 boys/10 girls) and the group with signs and symptoms - SSTMD group (10 boys/10 girls), respectively. There were significant statistical difference between group scores for DI, PI and CMI ($p<0.05$; Table 1). To be included in SSTMD group, the subjects had to have at least one symptom of the condition.

Ultrasonography

The masseter and anterior temporalis evaluation was conducted using the Just-Vision 200 digital ultrasonography system (Toshiba Corporation, Japan) and the images were obtained with a high-resolution real-time 56mm/10-MHz linear-array transducer. All subjects were examined by one of the authors who had no information regarding symptoms or CMI scores. The transducer was positioned against the skin surface over the central portion of the masseter muscle (the area of greatest lateral distention) and for anterior temporalis it was placed just in front of the anterior border of the hair line. The transducer was gradually shifted to obtain optimal visualization. The distance was measured directly on the screen. The measurements were recorded immediately both in the relaxed and clenching states of the jaws. The scanning was performed twice for each site and the means were used for statistical analysis.

The errors of measurement (Se) for the thickness of masticatory muscles were assessed from repeated measurements on two separate occasions (m1, m2) of 20 randomly selected subjects (n), using the Dahlberg's formula: $Se = \sqrt{\Sigma (m1 - m2)2 / 2n}$. The error was 0.47 mm for the contracted and 0.26 mm for the relaxed masseter and 0.32 mm for the contracted and 0.29 mm for the relaxed anterior temporalis.

Craniofacial Dimensions

The facial morphology of the subjects was evaluated by one calibrated examiner on cephalograms taken with the mandible in the intercuspal position. Traits of facial and dentoalveolar morphology were measured directly on profile radiographs. Measurements included anterior (n-gn, n-me, sp-gn) and posterior (S-tgo) vertical facial dimensions, mandibular inclination (NSL/ML), vertical jaw relationship (NL/ML), gonial angle (ML/RL) and incisor relations (overbite:ii-io, overjet: is-io). Angular measurements were recorded to the nearest 0.5º and linear measurements to the nearest 0.5 mm without correction for enlargement. The analyzed variables are described in Figure 1.

There was no significant difference between two sets of measurement, and the method errors of the individual measurements were 1.2mm and 0.5^{o}.

Bite force determination

Bite force was determined with a pressurized transducer, which consisted of a pressurized rubber tube connected to a sensor element (MPX 5700 – Motorola SPS, Austin, TX, USA). The tube and the sensor were connected to a converse analog/digital electronic circuit, fed by an analogical signal coming from the pressure-sensitive element. The system was connected to a computer where the data were analyzed.

Three bite force evaluations were conducted in each patient, who bit the tube with maximum force 3 times successively for 5 s, with a 10s interval among each bite. The tube was placed between the posterior maxillary and mandibular first molars bilaterally. To obtain the highest bite values possible, the adolescents were trained and urged to do their very best. They were seated in chairs with their heads fixed, keeping the Frankfort plan approximately parallel to the floor. In relation to numeric results, the minimum values were obtained, which corresponded to the initial pressure in the pressurized tube, and the maximum values corresponded to maximum bite force. The difference between maximum and minimum pressures for each evaluation was calculated and the mean value of the three, for each patient, was selected. The values from the pressurized tube were obtained in pounds per square inch (psi) and later these values were converted into Newtons (N), taking in account the area of the tube, since force is equal pressure x area.

The reliability of the bite force measurements was determined on 15 randomly selected volunteers in the same age group. These subjects underwent bite-force measurements at intervals of 14 days. The method error was s(i)=5.04 N.

Statistical Analysis

We performed multivariate analysis of variance with muscle thickness of the masseter and the anterior temporalis as the dependent variables. Gender was a between-subject factor. Weight and height were covariates.

Subsequently, the relation among bite force magnitude, the craniofacial dimensions, the jaw muscles thickness were assessed by Pearson's coefficient and stepwise multiple regression analysis. We used multivariate analysis of variance to compare the morphology parameters between groups. The relation between the craniofacial dimensions and the CMI and subscales was assessed by Spearman's coefficient, due to the indexes normality absence. Maximum bite force between groups was compared using non-paired "t" test and muscle thickness between sides and before and after contraction using paired "t" test. For all statistical analyses, the SPSSx package (SPSS 9.0; SPSS, Chicago, IL, USA) was used.

Results

The descriptive statistics for Craniomandibular Index and subscales and also the muscle thickness for masseter and anterior temporalis relaxed and during maximum contraction are shown in Table 1. The results showed that the muscles thickness increased significantly from the relaxed to the maximally contracted state ($p<0.05$). The SSTMD Group presented smaller values for bite force than Control Group (302 ±24N and 326±40N, $p<0.05$, respectively). There were no statistical significance for the cephalometric variables between groups ($p>0.05$). Multivariate analysis of variance yielded that the covariates (weight and height), had a significant influence on the thickness of masseter and anterior temporalis muscles (weight: $p=0.010$ and height: $p=0.005$).

In the control group, the bite force was negatively correlated to NSL/ML and overbite. There were also negative significant correlations between relaxed temporalis and n-gn, sp-gn, n-me and the same for the contracted temporalis except for the correlation for sp-gn which was not significant. We observed positive correlations between relaxed masseter and n-gn, sp-gn and S-tgo (Table 2).

In the SSTMD group the bite force and the relaxed and contracted masseter were significantly correlated to S-tgo. Furthermore, the contracted masseter correlated with n-gn and n-me. Negative correlations were found for relaxed and contracted masseter and contracted temporalis and NSL/ML and NL/ML. The relaxed temporalis was also negatively correlated to ML/RL (Table 3).

Multiple regression analysis showed that in the control group the overjet and NSL/ML contributed for more than 50% to the variance in bite force. In the SSTMD group, the contracted masseters explained 39% of the variance.

In the control group the cephalometric variable NSL/ML was negatively correlated with DI and positively correlated with PI (Spearman's correlation). In the SSTMD group, there was a significant positive correlation between DI and is-io and negative correlations between PI and n-gn and n-me and between CMI and S-tgo (Table 4).

Discussion

The decision to implement a dysfunction index in the present study, specifically the CMI, was based on the possibility of clinically measuring the severity of problems in mandibular movements, joint sound, and muscle and joint tenderness, using clearly defined criteria, simple clinical methods and easy scoring. In addition, this index has a good intra and inter-examiner correlation (Fricton and Schiffman, 1987). Therefore, the subjects' evaluation method used in the present study was the CMI, which has established validity and reliability (Fricton and Schiffman, 1987). Recently, the operational definitions for CMI were redesigned to conform precisely to those of the RDC/TMD (Dworkin and LeResche, 1992) resulting in a clinical evaluation protocol – the Temporomandibular Index (TMI). Ideally, criterion validity would be measured relative to a "gold standard" (Pehling *et al*., 2002). As no such standard exists for TMD, criterion validity of a new index requires its comparison to an accepted index that measures the same construct. Since the CMI has been used and validated repeatedly in clinical studies, the TMI was compared to it. Criterion validity of the TMI and CMI showed excellent agreement (0.97) (Pehling *et al*., 2002). Because the CMI/TMI instruments include almost the same examination items as the RDC/TMD, the diagnostic outcomes would be expected to be similar to that of RDC/TMD (Pehling *et al*., 2002). To avoid using subjective and descriptive report in assessment of the severity of TMD, CMI is recommended as clinical criteria (Fu *et al*., 2002). Besides, we decided to use the CMI because we also had a professional in our Dental School, who was calibrated in this index.

In the present study, the bite force was significantly lower in the SSTMD group when compared to the matched controls. According to Ahlberg *et al*. (2003)

temporomandibular joint discomfort was significantly negatively associated with bite force in the molar region. A high score on Helkimo's Clinical Dysfunction Index related to muscle tenderness and 'long face' type of craniofacial morphology was also associated with smaller values for bite force (Sonnesen *et al*., 2001). Our results corroborate the idea that maximum bite force could be reduced by pain in jaw-closing muscles or in the TMJ (Bonjardim *et al*., 2005).

The current research showed that muscle area increased significantly from the relaxed to the maximally contracted states, as also verified by Bakke *et al*. (1992), what is predictable despite the muscle shortening during contraction. For muscle contraction the individuals were asked to clench maximally in the intercuspal position, which was chosen because any other position might have influenced the vertical dimensions of the masseter, and thus the muscle thickness by stretching. However, since occlusal premature contacts were not taken into account, it is possible that this position does not always coincide with maximum muscle activation bilaterally and therefore, in some cases, the muscle thickness measurements might not be indicative of the true contraction potential of the muscles. The extent of occlusal contacts affects the muscle activity and a reduction in the number of occlusal contacts might result in an insufficient development of masticatory muscle strength (van Spronsen *et al*., 1996).

The multivariate analysis of variance showed that the covariates weight and height influenced the muscle thickness. The relation between 'height' and 'weight' on the one hand and 'muscle thickness' on the other, in subjects with signs and symptoms of TMD is still not well studied. According to Raadsheer *et al*. (1996, 1999) and Kiliaridis and Kalebo (1991) body variables also influenced muscle thickness. The influence of body variables is in agreement with the idea that the puberty stage increases the body mass and stature, leading also to a proportional increase in muscle thickness.

In the control group there were negative correlations between bite force and jaw inclination (NSL/ML) and overbite. Previous study has found that low bite force is associated negatively to mandibular inclination (Raadsheer *et al*., 1999). In the SSTMD group, there was a significant positive correlation between bite force and masseter thickness. According to Raadsheer *et al*. (1999), the only muscle that showed a significant relation with bite force was the masseter. In the present research, in both groups there were significant correlations between craniofacial morphology and masseter and anterior temporalis thickness. The masseter thickness, was weakly positively correlated to anterior facial dimensions (n-gn, n-me, sp-gn). However, there were stronger correlations for the posterior facial dimension (s-tgo), and also negative correlations for the mandibular inclination (NSL/ML and NL/ML), indicating that short face individuals seems to have a thicker masseter (Raadsheer *et al*., 1999). Farella *et al*. (2003) stated that the masseter muscle was significantly thicker (+15%) in the short-faced than the normal- to long-faced subjects. The anterior temporalis was negatively associated to anterior facial dimensions in the control group, and with gonial angle in the SSTMD group. These results suggest that long face subjects present thinner anterior temporalis muscles. Van Spronsen *et al*. (1991) also found a relation between the temporalis cross-sectional area and facial morphology. A negative significant correlation was found between the flexure of the cranial base and the temporalis cross-section.

Multiple regression analysis in the present research showed that the overjet and the mandibular inclination (50%) in the control group and the masseter thickness (39%) in the SSTMD group were the most important factors explaining the bite force variance respectively. These results are in accordance to Raadsheer *et al*. (1999), who also found that the masseter thickness was the main contributor to the variance in bite force magnitude. The absence of an influence of masseter thickness on bite force variance in the control group can be explained by the lower standard deviation for this variable in the present sample. This indicates that the range of muscle thickness is smaller in the control group than in the SSTMD group.

The correlations between craniofacial dimensions and the signs and symptoms of TMD showed that mandibular inclination is negatively associated with the DI and stronger positively correlated to PI in the control group. These results are in agreement with Sonnesen *et al*. (2001), who suggest the occurrence of muscular tenderness in subjects whose morphological traits are consistent with a long face craniofacial morphology. Surprisingly, on the other hand, in the TMD group, there were negative correlations for PI and anterior facial dimensions (n-gn and n-me). This may be due to the fact that the adolescents comprising the SSTMD group were most short-face subjects. This was based on the anterior to posterior ratio and also by the fact that the posterior dimension (S-tgo) was negatively correlated to CMI in this group. The overjet was positively correlated to DI, which is in accordance to Pahkala and Qvarnstrom (2004) who found that excessive overjet was the only variable which seemed to consistently increase the risk of TMD.

In conclusion, the present findings support the concept that subjects with different craniofacial morphology show muscular differences. However, it does not seem possible to draw any firm conclusions regarding the presence of any particular morphology in adolescents with symptoms or signs of TMJ dysfunction, since there was no difference for the morphology parameters between groups ($p>0.05$). On average, TMD signs and symptoms were seen in connection to increasing overjet and long-face characteristics, but no particular trait can be considered predictive of dysfunction. On the other hand, the associations provide an insight into possible risk factors, and may therefore be of importance for a better understanding of the occurrence of symptoms and signs of TMD.

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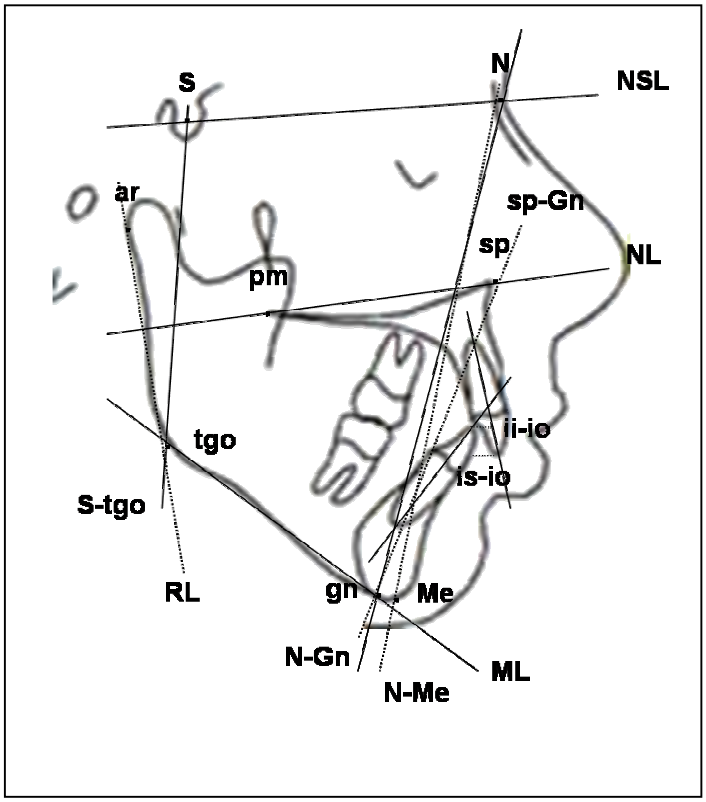

Figure 1: Reference points and lines in the cephalmogram

Anterior (n-gn, n-me, sp-gn) and posterior (S-tgo) vertical facial dimensions, mandibular inclination (NSL/ML), vertical jaw relationship (NL/ML), gonial angle (ML/RL) and incisor relations (overbite:ii-io, overjet: is-io).

Table 1. Dysfuntion Index (DI), Palpation Index (PI) and Craniomandibular Index (CMI), muscle thickness in Control and SSTMD groups.

RR: right relaxed; RC: right contracted; LR: left relaxed; LC: left contracted

Control				Masseter Thickness (mm)				Anterior Temporalis Thickness (mm)			
	DI	PI	CMI	RR	RC	LR	LC	RR	RC	LR	LC
Median	0.07	0.00	0.04	10.10	13.35	10.00	12.95	3.05	4.40	3.05	4.55
(25%)	0.04	0.00	0.02	9.10	12.45	9.48	12.00	2.50	4.10	2.50	3.90
(75%)	0.07	0.00	0.04	10.80	14.90	10.55	14.00	3.30	4.90	3.35	5.05
Mean	0.06[a]	0.01[a]	0.03[a]	10.02	13.57	9.99	13.03	2.96	4.46	2.98	4.56
SD	0.03	0.02	0.01	1.09	1.30	0.80	1.38	0.56	0.91	0.55	0.72
SE	0.01	0.00	0.00	0.24	0.29	0.18	0.31	0.13	0.20	0.12	0.16
SSTMD											
Median	0.14	0.31	0.23	10.50	12.85	10.15	12.65	2.80	4.25	2.85	4.30
(25%)	0.10	0.22	0.18	9.78	12.00	9.63	11.38	2.60	3.80	2.60	3.95
(75%)	0.21	0.37	0.24	11.85	14.30	11.55	14.48	3.35	4.80	3.05	4.65
Mean	0.16[b]	0.31[b]	0.23[b]	10.72	13.40	10.40	13.23	2.95	4.19	2.84	4.25
SD	0.10	0.17	0.09	1.62	1.99	1.68	2.20	0.62	0.86	0.34	0.59
SD	0.02	0.04	0.02	0.36	0.45	0.38	0.49	0.14	0.19	0.08	0.13

[a,b] Pairs of values for the DI, PI and CMI variables between groups with different superscript letters in the same vertical line are significantly different ($p<0.05$)

Table 2: Pearson's correlation coefficients (R) and p values

		Control Group							
		MC	TR	n-gn	sp-gn	NSL/ML	ii-io	S-tgo	n-me
BF	R					-0.44	-0.61		
	p					0.05*	0.01*		
MR	R	0.69		0.45	0.45			0.51	
	p	0.00*		0.05*	0.05*			0.02*	
MC	R								
	p								
TR	R			-0.49	-0.45				-0.55
	p			0.03*	0.05*				0.01*
TC	R		0.81	-0.48					-0.56
	p		0.00*	0.03*					0.01*

* $p<0.05$

Bite force (BF), relaxed masseter (MR), contracted masseter (MC), relaxed temporalis (TR), contracted temporalis anterior (TC), anterior (n-gn, n-Me, sp-gn) and posterior facial dimensions (S-tgo), mandibular inclination (NSL/ML), vertical jaw relationship (NL/ML), gonial angle (ML/RL), overbite (ii-io) and overjet (is-io)

Table 3: Pearson's correlation coefficients (R) and p values

		SSTMD Group									
		MR	MC	TR	n-gn	NSL/ML	NL/ML	ML/RL	ii-io	S-tgo	n-me
BF	R	0.45	0.63							0.45	
	p	0.05*	0.00*							0.05*	
MR	R		0.86			-0.74	-0.50		-0.51	0.80	
	p		0.00*			0.00*	0.03*		0.02*	0.00*	
MC	R				0.05	-0.58	-0.49			0.79	0.48
	p				0.03*	0.01*	0.03*			0.00*	0.03*
TR	R							-0.54			
	p							0.02*			
TC	R			0.72		-0.49	-0.47				
	p			0.00*		0.03*	0.04*				

p<0.05

Table 4: Spearman's correlation coefficient (R) and p-values

		SSTMD Group				Control Group
		n-gn	is-io	S-tgo	n-me	NSL/ML
DI	R		0.63			-0.45
	p		0.00*			0.05*
PI	R	-0.54			-0.54	0.56
	p	0.01*			0.02*	0.01*
CMI	R			-0.45		
	p			0.05*		

* $p<0.05$
Dysfunction Index (DI); Palpation Index (PI) and Craniomandibular Index (CMI)

Bite force and its correlation with clinical signs of temporomandibular dysfunction in mixed and permanent dentition

Bite force and clinical sings of TMD

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Abstract

The aim was to evaluate bite force (BF) magnitude and its correlation to the severity of signs of temporomandibular dysfunction (TMD), gender, weight, height and age in 101 scholars ranging 6-18 years-old (32 boys/21 girls in mixed dentition and 23 boys/25 girls in permanent dentition). TMD clinical signs were evaluated using the Craniomandibular Index (CMI), and two subscales, the Dysfunction and the Palpation Indexes (DI, PI). BF was determined with a pressurized tube connected to a sensor (MPX5700-Motorola SPS, USA). ANOVA, Tukey test, Pearson's and Spearman's coefficients were applied. BF was higher in the permanent dentition ($p<0.05$). There were no difference in BF between genders inside the groups, but boys in the permanent dentition had higher values than children in the mixed dentition ($p<0.05$). The girls in the permanent dentition presented negative correlation in BF with PI and CMI ($p<0.05$). BF was positively correlated with weight, height and age in the permanent dentition ($p<0.05$). It was concluded that BF increased from mixed to permanent dentition, assuming an influence of body variables and aging in its enhancement. The TMD signs in older girls were correlated to decreasing bite force, suggesting an influence of muscle tenderness preventing subjects from exerting maximum BF.

Key words: Temporomandibular joint disorders, dentition, bite force, body height, body weight, age

Introduction

Epidemiologic studies have shown that signs and symptoms of temporomandibular dysfunction (TMD) can be found in all age groups (1-4). TMD in children is considered to have a multifactorial etiology (5-7). Because of the difficulty in establishing a precise etiology, TMD is often defined on the basis of signs and symptoms, the most common of which are: TMJ and muscle pain, limited mouth opening, clicking and crepitation (8,9).

The bite force has an influence on muscle efficiency and development of the masticatory function (10). Bite force tend to increase with the need to chew (11), with body weight and body height but decreases with changes in dentition and also in the presence of pain (12,13). Bite force increase with teeth in occlusal contact and with increasing number of erupted teeth and with increasing stages of dental eruption (12, 14).

Individuals with TMD are expected to have decreased maximum bite forces. TMD patients use greater relative masticatory forces than normal subjects during chewing (15). On the contrary, the weakness of masticatory muscle has been considered to be a predisposing factor for TMD (16). An increase in bite force up to normal levels has been reported following successful treatment of TMD (17,18), with a positive effect on the masticatory function, as both masticatory efficiency and occlusal force endurance improved after treatment (19). It has been found in children that muscle tenderness is associated with a low bite force. Furthermore, a high score on Helkimo's clinical Dysfunction Index (DI) was also associated with low bite force (20). There have been few studies about the association between maximum bite force and the presence of TMD during childhood. Since reduced strength is an important factor in overload and hyperactivity of masticatory muscles and a common feature of patients with TMD, assessment of bite force is relevant in the diagnosis and treatment plane (21).

Clinicians have been interested in bite force with regard to its potential influence on the development of the masticatory system. Therefore, to elucidate the causes of influence of TMD in bite force, it is of a great importance to examine the gender differences in muscle tolerance in response to the hyperactivity (22) and the relationship between various physical characteristics, i.e. age, gender, height, and weight (23).

Thus, the aim of this study was to evaluate bite force magnitude and its correlation to clinical signs of temporomandibular dysfunction, gender, weight, height and age in the mixed and permanent dentition.

Material and Methods

The study comprised 101 children of both genders aged 6 – 18 years, who were to start dental treatment at the Department of Pediatric Dentistry (Piracicaba Dental School, State University of Campinas). The children and their parents consented to participate in the study, and the research was approved by the Ethics Committee of that Dental School.

The sample was selected after a complete anamneses and clinical examination, verifying a healthy state, the presence of all teeth without anomalies and alterations of form, structure or number, and the normality of oral tissues. All kinds of morphological occlusion were included in this study, since bite force has been shown not to vary significantly among Angle maloclusion types (14). Body weight and height were determined.

Initially, the signs of TMD were assessed, according to the Craniomandibular Index (CMI), as described by Fricton and Schiffman (24). The CMI has a 0–1 scale that measures tenderness and dysfunction in the stomatognathic system and includes all currently recognized signs of TMJ disorders (24,25). There are two subscales: the Dysfunction Index (DI) and the Palpation Index (PI). The DI is designed to measure limitation in mandibular movement, pain and deviation in movement, TMJ noise, and TMJ tenderness. The PI measures the prevalence of muscle tenderness in the stomatognathic system. In this way, this index separates joint problems from muscle problems.

After all parameters had been checked, the children were separated to integrate the mixed dentition group and the permanent dentition group, respectively. Sample distribution is shown in Table 1.

Bite Force Measurements

Maximal bilateral bite force was determined with a pressurized transducer, which was constructed with a flexible tube connected to a sensor element (Motorola MPX5700) (26). A computer and software were used to read the pressure change in Basic language and data were transferred to Excel™. The values were obtained in pounds per square inch (psi) and were later converted into Newtons (N), taking into account the area of the tube, since force is equal pressure x area. The recordings were made three times, with an interval of at least two minutes between them and the tube was placed bilaterally between the upper and lower first permanent molars. Since the transducer was placed only in contact with the first molars, the eruption phase of the permanent teeth in the mixed dentition was not influencing the measurement. The subjects, seated in an upright position with the head in natural posture, were instructed to bite as forcefully as possible. The difference between maximum and minimum values for each evaluation was calculated and bite force was determined as the maximum value of the three measurements (with an accuracy of 0.1N).

The reliability of the bite force measurements was determined on 15 randomly selected volunteers in the same age group as the subjects in the study having dental treatment. These subjects underwent bite-force measurements at intervals of 14 days, using the same method as in this study. There was no significant difference between the two sets of measurements and the Dahlberg's ($Se = \sqrt{\Sigma (m1 - m2)2 / 2n}$) method error of the individual measurements was s(i)=5.04 N.

Statistical analysis

Data were analyzed by descriptive statistical method. One way ANOVA and Tukey test as *post-hoc* were used to compare differences in bite force among groups, considering the stages of dentition and genders. Man-Whitney test compared the index values. The correlation between bite force and weight, height, age was determined by Pearson's coefficient and between bite force and the Index values by Spearman's coefficient, since the Index values did not have normal distribution. The significance level was set at $P \leq 0.05$.

Results

The descriptive statistic for bite force, weight, height, age, DI, PI and CMI is presented in Table 1. ANOVA showed a significant difference for bite force magnitude among boys with permanent dentition and boys and girls with mixed dentition ($p<0.05$).

However, girls with permanent dentition presented no difference within all the other groups.

The girls in the permanent dentition group presented negative significant correlations with PI and CMI. There were no significant correlations for bite force and the index values in mixed dentition ($p>0.05$) (Table 2).

Body variables and age presented significant correlations with bite force for boys and for girls in the permanent dentition group (Table 2). Nevertheless, in the mixed dentition group, there were no correspondent correlations.

Discussion

The decision to implement a dysfunction index in the present study, specifically the CMI, was based on the possibility of clinically measuring problems in mandibular movements, joint noise, and muscle and joint tenderness, using clearly defined criteria, simple clinical methods and easy scoring. Recently, the operational definitions for CMI were redesigned to conform precisely to those of the RDC/TMD (27) resulting in a clinical evaluation protocol – the Temporomandibular Index (TMI). Criterion validity of the TMI and CMI showed excellent agreement (0.97). Because the CMI/TMI instruments include almost the same examination items as the RDC/TMD, the diagnostic outcomes would be expected to be similar to those of RDC/TMD (28). To avoid using subjective and descriptive reports in assessment of signs of TMD, CMI is recommended as clinical criteria (29).

In this study, a sample composed of children and adolescents was selected with the aim of associating bite force magnitude to signs and symptoms of TMD, weight, height and age. This method had already been tested with good results, as published elsewhere (26,30).

The results of the present research showed that subjects in the permanent dentition stage had higher bite force values when compared with those with mixed dentition ($p<0.05$, Table 1). However, when the maximum bite force was compared between groups differing for gender, only boys with permanent dentition presented significantly higher values than the others. In the literature, it is widely reported that gender differences in bite force increases with age up to adolescence, with the first difference seen at puberty. The increase in muscle mass during puberty influenced by androgenic steroids creates the difference between male and female muscle strength (31). Ahlberg *et al*. (32) related that the mean maximum bite force value in the molar region was significantly higher in men than in women although not significant in the incisal region. Ikebe *et al*. (33) also found bite force significantly stronger in healthy men than in women. The mean values for bite force found in the present study sample (Table 1) were higher than those for primary dentition found by Rentes *et al.* (26) and lower than the values for adults found by Waltimo and Kononen (34) and Raadsheer *et al.* (35). These results are in accordance with the knowledge that bite force increases with age (36), explaining the higher values found in the permanent dentition comprised by older subjects.

The correlations between bite force and the index values were only significant for girls in the permanent dentition group for PI and CMI. No correspondent significant relationship was found in the mixed dentition group (Table 2). According to Egermark *et al*. (4) signs and symptoms of TMD have little prevalence in small children but increase with age in adolescence up to young adulthood. This could explain the correlation found in the permanent dentition group but not in the mixed dentition group, in which the children showed mild signs and symptoms of TMD. It has also been found that muscle tenderness was associated with low bite force in children (20). In a very recent study, a negative correlation between bite force and PI and CMI was also found, suggesting that muscle tenderness was correlated to decreasing bite force (30).

Some studies with older people have shown no association between TMD and maximal bite force. Probably, this fact is due to the age, as the elderly would appear not to present pain, but temporomandibular joint noise (TMJ) or mouth opening limitation for example, as the major contributing factor to TMD, i.e. functionally adapted to the internal derangement of TMJ (33).

According to Ahlberg *et al*. (32) there was significant negative association of TMD with bite force in the molar region. A high score on Helkimo's Clinical Dysfunction Index related to muscle tenderness and 'long face' type of craniofacial morphology was also associated with lower bite force values, attributed to a functional overloading of weak mandibular elevator muscles (20). An alternative explanation is that the tenderness may lead to a temporary hypofunction of the masticatory muscles and a resulting reduction in bite force (37).

In the present results it is important to note, that there was no significant difference in bite force between girls in mixed and permanent dentition ($p>0.05$) (Table 1). This could be a result of the presence of signs and symptoms of TMD that might have influenced the bite force magnitude in the permanent dentition girls, since there was a negative correlation between bite force and PI. Even at young ages, girls seem to be more affected by TMD signs and symptoms, and this can also lead to a decrease in bite force (30). These outcomes could provide evidence of gender differences in pain perception, as women have been reported as having more clinical pain, lower pain threshold and tolerance levels than men and are vulnerable to the development and maintenance of musculoskeletal pain conditions (38).

In relation to the influence of body variables on bite force magnitude, the current results showed that only in permanent dentition were the correlations between bite force and weight, height and age significant. These results agree with a previous study that also verified that bite force increased according to body variables (39). However, there was no relationship between bite force and weight, height and age in the mixed dentition group, which is also in agreement with Kiliaridis *et al*. (40), who also observed no statistically significant correlations in children 7-13 years of age. The influence of body variables only in permanent dentition is in agreement with the idea that the puberty stage increases the body mass and stature and also leads to a proportional increase in bite force.

From this study, it may be concluded that maximum bite force increased from mixed to permanent dentition. Body variables, as well as age, had significant correlation with bite force only in permanent dentition, but not in mixed dentition. Furthermore, in permanent dentition, the signs of TMD, especially those related to muscle tenderness in girls, were shown to be correlated to decreasing bite force, suggesting an influence of muscle tenderness preventing subjects from exerting maximum bite force.

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Table 1. Descriptive analysis for weight (Kg), height (m), age (years), bite force (N), Dysfuntion Index (DI), Palpation Index (PI) and Craniomandibular Index (CMI) separated by gender and type of dentition

BMD	N	Mean	SD	SE	Max	Min	Median	25%	75%
Height	32	1.38[a]	0.08	0.01	1.55	1.19	1.39	1.33	1.45
Weight	32	34.58[a]	7.37	1.30	48.50	22.50	32.75	28.65	40.85
Age	32	9.50[a]	1.48	0.26	11.00	6.00	10.00	9.00	10.50
Bite force	32	356.98[a]	48.13	8.50	461.10	262.88	350.98	323.44	373.00
DI	32	0.04[a]	0.04	0.01	0.15	0.00	0.03	0.02	0.07
PI	32	0.06[a]	0.10	0.01	0.36	0.00	0.02	0.00	0.12
CMI	32	0.05[a]	0.05	0.01	0.20	0.00	0.03	0.02	0.091
GMD									
Height	21	1.34[a]	0.10	0.02	1.530	1.15	1.36	1.26	1.42
Weight	21	31.06[a]	10.05	2.19	61.500	20.50	28.00	24.75	33.75
Age	21	8.81[a]	1.25	0.27	11.000	6.00	9.00	8.00	10.00
Bite force	21	345.73[a]	41.44	9.04	406.040	251.87	350.98	317.94	375.75
DI	21	0.06[a]	0.07	0.01	0.269	0.00	0.03	0.03	0.08
PI	21	0.12[a]	0.18	0.03	0.591	0.00	0.04	0.00	0.18
CMI	21	0.09[a]	0.10	0.02	0.358	0.00	0.04	0.02	0.13
BPD									
Height	23	1.58[b]	0.12	0.02	1.830	1.39	1.60	1.45	1.65
Weight	23	50.30[b]	14.31	2.98	83.700	26.30	47.50	40.12	62.37
Age	23	13.13[b]	2.24	0.46	18.000	10.00	12.00	12.00	14.00
Bite force	23	387.36[b]	27.66	5.76	428.060	350.98	373.00	361.99	417.05
DI	23	0.08[a]	0.05	0.01	0.214	0.00	0.07	0.03	0.13
PI	23	0.11[a]	0.15	0.03	0.477	0.00	0.00	0.00	0.23
CMI	23	0.09[a]	0.09	0.01	0.310	0.00	0.03	0.02	0.17
GPD									
Height	25	1.57[b]	0.10	0.02	1.730	1.37	1.60	1.47	1.66
Weight	25	51.94[b]	11.42	2.28	72.000	30.00	52.00	46.25	57.82
Age	25	13.44[b]	2.32	0.46	18.000	9.00	13.00	12.00	14.25
Bite force	25	361.10[ab]	38.40	7.68	417.050	262.88	361.99	337.20	395.02
DI	25	0.12[a]	0.10	0.02	0.428	0.00	0.10	0.06	0.14
PI	25	0.17[a]	0.20	0.04	0.704	0.00	0.06	0.00	0.30
CMI	25	0.14[a]	0.13	0.02	0.532	0.01	0.14	0.03	0.23

BMD: boys mixed dentition; GMD: girls mixed dentition; BPD: boys permanent dentition; GPD: girls permanent dentition; Min: minimum; Max: maximum.

[a, b] Pairs of values for height, weight, age, bite force, DI, PI and CMI among groups having different superscript letters are significantly different ($p<0.05$)

Table 2: Person's (BF and weight, height and age) and Spearman's (BF and DI, PI, CMI) correlation coefficients

		Weight	Height	Age	DI	PI	CMI
BF BMD	R	-0.116	-0.252	-0.268	0.080	0.068	0.114
	p	0.53	0.16	0.14	0.66	0.71	0.53
BF GMD	R	0.201	0.084	0.044	-0.334	0.193	0.115
	p	0.38	0.72	0.85	0.14	0.40	0.62
BF BPD	R	0.422	0.510	0.412	0.148	0.077	0.057
	p	0.05*	0.01*	0.05*	0.50	0.73	0.80
BF GPD	R	0.565	0.428	0.451	-0.264	-0.480	-0.429
	p	<0.01*	0.03*	0.02*	0.20	0.02*	0.03*

*$p \leq 0.05$

BMD: boys mixed dentition; GMD: girls mixed dentition; BPD: boys permanent dentition; GPD: girls permanent dentition

MASTICATION: INFLUENCE OF SALIVA, FOOD, DENTITION, MUSCLE FORCE AND TEMPOROMANDIBULAR DISORDERS

Review Article

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Mastication: influence of saliva, food, dentition, muscle force and temporomandibular disorders

Review Article

Abstract

Mastication is a complex process, involving activities of the facial, the elevator and suprahyoidal muscles and the tongue. These activities result in patterns of rhythmic mandibular movements, food manipulation and the crushing of food between the teeth. Saliva facilitates mastication; moistens the food particles, makes boluses, and assists swallowing, whereas food consistency modifies masticatory forces, the mandibular jaw movements, the duration of the mastication cycle and the number of cycles preceding the first swallow. Jaw elevator EMG activity research showed a clear relation between muscular activity and food properties. The teeth, masticatory muscles and temporomandibular joints are also important because they form together the mechanism where the food particles are fragmented. This study presents an update and synopsis of saliva, food, dentition, muscle force and temporomandibular disorders effects on the masticatory process. Apparently, hard and dry products require more chewing cycles and longer time in mouth until swallowing for sufficient breakdown to take place and for enough saliva to be added to form a coherent bolus safe for swallowing. Product characteristics, the amount of saliva, dentition and bite force affect the chewing performance.

Key words: chewing efficiency, dental state, swallow.

Introduction

Mastication is the first oral step in the process of digestion. The food is prepared for swallowing and further processing in the digestive system. During chewing, the food particles are reduced in size, while saliva is produced to moisten and lubricate the food so that it can be swallowed [1].

Chewing is a complex sensory-motor activity whereby the ingested food is first transported to the post-canine teeth by the tongue and then processed into a bolus suitable for swallowing. This involves the breakdown of solid food, the incorporation of saliva, the agglomeration and shaping of the resulting mixture into a cohesive bolus, and finally the transport of the bolus to the pharynx [2].

The control of mastication is executed by a rhythmic activity of the brain stem [3] that can be overridden by the higher centers and modified by peripheral information [4].The urge to swallow food can be triggered by a threshold level in the food particle size as well as by degree of lubrication of the food bolus [5-7]. During mastication it is likely that mechanoreceptors in the gingival tissues will be stimulated, which may result in salivary flow [8,9].

Evidence from animal and human studies suggests that increased mastication may increase salivary output, whilst reductions in the masticatory effort have the reverse effect [10]. An increase in the salivary flow rate follows implementation of a diet which requires more mastication [11].

There are several factors determining the chewing result. The teeth are important in the masticatory system. They form the occlusal area where the food particles are fragmented. This fragmentation depends on the total occlusal area and thus on the number of teeth [12]. Bite force is also one of the components of the chewing function and it is exerted by the jaw elevator muscles. It depends on muscle volume, jaw muscle activity, and the coordination between the various chewing muscles [12,13]. Measurement of the maximum bite force is an attempt to quantify the total force of the jaw closing muscles [14].

Moreover, decreased chewing ability is expected in patients with problems in the temporomandibular joint (TMJ). Restoration of chewing ability is therefore an important goal in the treatment of temporomandibular disorders (TMD) [15].

In addition to reflex control, cognition can influence food perception and breakdown in the mouth [10]. Mastication may depend on the type of food and its interaction with saliva, teeth and biomechanical system. The aim of this study was to present an update and synopsis of saliva, food, dentition, muscle force and TMD effects on the mastication process.

Mastication

Mastication is a process in which pieces of food are ground into a fine state, mixed with saliva, and brought to approximately body temperature in readiness for transfer to the stomach where most of the digestion occurs [16]. Pulverization of food is the main function of mastication, but it also imparts enjoyable sensations that fill a basic human need.

Mastication is a complex process, involving activities of the facial, the elevator and suprahyoidal muscles and the tongue. These activities result in patterns of rhythmic mandibular movements, food manipulation and the crushing of food between the teeth.

Integral motor control is a requirement for the ability to masticate foods, but an intact dentition is also important.

Basic chewing rhythms are generated centrally in the absence of sensory feedback by the so-called central pattern generator (CPG) which has been suggested to be located in the medial bulbar reticular formation [17]. However, mastication is a behaviour that has to adapt to environmental demands through the mediation of both peripheral and central inputs to the CPG. Mechanoreceptors in the oral cavity and jaw-closing muscle spindles serve as important sensory inputs for regulation of jaw movement pattern and masticatory force [18-20].

The CPG of rhythmical masticatory movements can be divided into three processes: (a) generation of the masticatory rhythm, (b) generation of a pattern of activities of the jaw, tongue and facial muscles, and (c) coordination of the activities of these muscles [17]. There are several lines of evidence that the masticatory CPG is functionally subdivided into two neuronal groups: one for generation of masticatory rhythm, giving the timing signal for rhythmical alteration of jaw closing and jaw opening (central rhythm generator, CRG), and the other for generation of the spatiotemporal pattern of activities of the jaw, tongue and facial muscles. The central motor command for the actual pattern of the masticatory movement is assumed to be generated by a certain neuronal population, which receives rhythmical input from the CRG, integrates the input with other central and peripheral inputs and sends the command to cranial motoneurons innervating the jaw, tongue and facial muscles [17].

At it simplest, mastication consists of rhythmic activity of the jaw-opening and –closing muscles regulated by a central pattern generator [21]. This basic rhythm is modulated by sensory inputs throughout the chewing sequence, allowing adjustment of the masticatory process to the bolus texture at any moment according to a precise feedback control [4,22-24]. During mastication, the major jaw elevator muscles are used to overcome food resistance [4,25].

The masticatory sequence is the whole set of movements from ingestion to swallowing [26]. It is made up of masticatory cycles that change in form as the food is gathered, moved backward to the molar teeth, then broken down and prepared for swallowing.

Saliva

Variations in individual salivary flow rates can be as high as 50% over a day due to circadian rhythms [27], and can increase up to four-fold from resting levels upon stimulation [27,28]. Salivary flow seems to increase according to meals time schedule, decreasing in the intervals between them.

It has been shown that the production of sufficient saliva is indispensable for good chewing [29]. Saliva helps mastication, makes boluses, and assists swallowing [30]. The important role of saliva for chewing and swallowing is demonstrated by the finding that the number of chewing strokes, hence time in the mouth needed for swallowing significantly increases after experimentally induced oral dryness [31].

In addition to water, one of the contents of saliva is mucins, which cover and protect the oral cavity [32,33]. Mucins also provide saliva with its lubricative properties and facilitate manipulation, mastication and swallowing [34].

While saliva and chewing have been shown to be interrelated, the relationship between amount of saliva and mastication has not been extensively studied [35]. Previous recent research has shown that there was only a weak correlation between a subject's unstimulated and stimulated salivary flow rates and one's sensory ratings [36]. A possible explanation for this could be that subjects have their own references and that ratings are relative rather than absolute and probably a result of experience. Subjects are apparently used to the volumes of saliva in their mouths, and the systems thus seem to be calibrated for the subjects' individual salivary levels during eating. Assuming this is the case, it can be hypothesized that an artificial increase in the amount of saliva could influence the sensory ratings [36]. However, recent data from our laboratory have revealed that there is no influence of additional saliva related solutions (water, artificial saliva rich in mucins and α-amylase solution) on physiological parameters, like muscle activity or swallowing threshold, except for dry food (Pereira et. al., unpublished data). It seems that an interaction between fluid and food is necessary, since there is low influence of salivary flow on swallowing threshold.

Saliva is also expected to be involved in our perception of taste, flavor and texture of foods [36]. Some studies have investigated the effect of saliva on selected sensory attributes [36-38]. The mixing of saliva with food can influence flavor [39] and can cause taste and flavor substances to be diluted. The α-amylase is an enzyme present in saliva and it initiates the digestion of starch, playing a role in the initial breakdown of food [40] and may cause a drop in perceived thickness of the food. However, some studies using additional α-amylase solutions during chewing of natural food failed to show an influence of this enzyme on most of sensory attributes studied [36,40] in custard deserts. For starch-based vanilla custard desserts, amylase resulted in increased melting and decreased thickness sensations, whereas acarbose (an amylase inhibitor) had the opposite effect. Neither additional amylase nor acarbose affected sensations for a nonstarch-based custards [40]. For solid foods, it was observed that α-amylase solution has the same effect as water in the perception of sensory attributes (Pereira et. al., unpublished data).

Food Properties

Food has a large influence on the mastication process [24,41,42]. An apparent connection between muscular activity and food properties has been reported [43,44]. The number of chewing cycles preceding the first swallow is also related to the food [6]. A firm and dry food, requires many chewing cycles to splinter before they can be swallowed [6]. Taste of food also has much influence on the chewing process [45,46].

Appearance, flavour and texture are the three main acceptability attributes of food that provide enjoyment in eating. Whatever form the food takes, it must be converted into a liquid during the process of mastication to allow it to be swallowed [16].

Food texture modifies masticatory forces [47], the mandibular jaw movements [48], the duration of the mastication cycle and the number of cycles preceding the first swallow [1,29]. Jaw elevator EMG activity research showed a clear relation between muscular activity and food properties (Figure 1) [42,44]. Moreover, the texture of food can be also related to the salivary flow rate.

Salivary flow during mastication depends on both the type and weight/seize of the food stimulus [49]. Indeed, in a study on rabbits, higher salivary flow rates were observed for dry food (dry pellets) than for moist food (pieces of carrot) [50]. The salivary flow rates observed for natural foods are much higher than for chewing test materials (Parafilm) to induce salivation. Parafilm is an inert and tasteless material, so it does not cause gustatory secretory stimulation. The effect of gustatory stimulation of food has been found to be more important than the mechanical stimulation of chewing for the saliva flow rate [51,52]. A recent research has shown that the amount of saliva secreted per minute for toast, cake and cheese was not different for the various foods and volumes. However, the amount of saliva secreted per gram of product differed significantly among the different types of foods. Toast elicited the highest levels, followed by cake and cheese [29]. Since toast contains the lowest percentage of water and fat, this is evidence that a dry product needs more saliva to moisten and form a cohesive bolus suitable for swallowing.

Food properties modify the transport duration of the bolus between the oral cavity and the oropharynx, but the duration of swallowing itself is not affected [53]. The moment of swallowing has been shown to be rather constant within a subject for one type of food, whereas large variations in the number of chewing cycles until swallowing are observed between subjects [29,54-56]. Food can vary largely in e.g. thickness, hardness, fat and moisture content. These differences are reflected in the force needed to shear food, the breakdown pattern of the food, the ease with which it is manipulated, formed into a bolus and swallowed. Type of food product has a significant effect on the number of chewing cycles until swallowing (Figure 2). Dry and hard products require more chewing cycles before swallowing [1]. Evidently, more time is needed to break the food down and to add enough saliva to form a cohesive bolus suitable for swallowing. Buttering dry foods significantly reduces the number of chewing cycles until swallowing [1]. Moreover, it has been proven also that the number of chewing cycles until swallowing is correlated among natural and artificial foods. This means that subjects, who use a small number of chewing cycles for one food, consistently use small numbers for all types of food [1].

Dental Status and Muscle Force

Masticatory performance results from a complex interplay of direct and indirect effects. The number of functional tooth units and muscle (bite) force are the key determinants of masticatory performance, which suggests that their maintenance may be of major importance for promoting healthful functional status [57].

Many factors related to dentition are known to have a large influence on masticatory performance, such as number of teeth, loss and restoration of postcanine teeth, number of occlusal contacts areas [56,58-64]. The relationship between masticatory performance and the number of occluding teeth is found to be linear [56]. In a recent research in our laboratory, the correlation between number of chewing strokes before swallowing and dental state was accomplished and the results showed that masticatory performance was significantly influenced by dentition, but not by age or gender [65]. Indeed, a clear relationship exists between dental state and masticatory performance as determined with a chewing test, *e.g.* [57,59,60,66-69].

On average, it was believed that subjects with an incomplete dentition, and thus a reduced masticatory performance, use more chewing strokes to prepare the food for

swallowing than subjects with a complete natural dentition [55]. They would compensate for their reduced capacity by chewing longer, but this could not prevent them from swallowing larger food particles [56]. According to a large sample of 87 subjects, bad chewers did not necessarily chew longer before swallowing than good chewers [65].
Subjects who need a relative low number of chewing strokes may be in the habit of eating faster, take less time to finish their meals or might feel less discomfort from distension of the soft tissues of the pharynx and oesophagus when they swallow a large bolus [6].

Subjects with a reduced dentition cannot pulverize their food to the same extent as subjects with more occlusal units, in a fixed number of chewing strokes. According to Fontijn-Tekamp et al., [65], the number of occlusal units was the only factor that affected the median particle size of masticatory performance and the swallowing threshold. However, the explained variance of the number of occlusal units was 16% only. On the other hand, a better determinant of masticatory function is the bite force[57] which alone could explain 40% of the variation in chewing efficiency [70].

Previous studies have shown that individuals use a certain percentage of their maximum bite force during chewing [71,72]. Therefore, a subject with a high muscle force will also use more force while chewing. This indicates that a higher bite force leads to a better fragmentation of the food. Significant correlations are reported between masticatory performance and muscle force for subjects with natural dentition, shortened arch as well as complete arch [73,74].

The chewing performance has also been studied in subjects with prosthesis. Denture wearers reach only 25% of dentate chewing performance. Chewing efficiency has been proven to be significantly better in patients with overdentures on dental implants than in patients with full dentures. However subjects with natural roots under their overdentures performed significantly better compared with subjects with dental implants. After implant treatment bite force and chewing performance nearly doubled [75, 76]. Edentulous groups were clearly less efficient than subjects with natural dentition [70]. Individuals also rate their chewing comfort and ability higher after implant treatment [6,77-82].

Temporomandibular disorders

Mastication is also influenced by disorders of the temporomandubular joint, although this influence is not very well described in the literature. Decreased chewing ability is one of the most important problems which patients with temporomandibular disorders (TMDs) encounter and restoration of chewing ability is therefore an important goal in the treatment of TMD [15].

The clinical temporomandibular disorders (TMD) pain-related disability was investigated by Yap et al., (2002) and the three most frequent jaw disabilities were: eating hard foods (77.6%), yawning (75.7%) and chewing (64.5%)[83].

Stegenga et al., [84] and Sato et al., [85] described reduced chewing ability caused by pain among patients with osteoarthrosis and internal derangement when compared to controls. Children with JRA (Juvenile Rheumatoid Arthritis) also compromise their masticatory function as a pain avoidance mechanism [86]. Changes of chewing movement and masticatory efficiency were examined in patients who had been diagnosed with non-reducing disc displacement of the TMJ but had not received any treatment, and it was reported that masticatory efficiency tend to improve spontaneously [87]. Patients that have a disorder longer than 3 years tend to display less reduction of their masticatory performance [88]. It is reported that the disorders reach a steady state 2-4 years after the onset of dysfunction, in which few signs and symptoms persist and do not influence the chewing ability [89].

Fifty patients with whiplash-associated disorders (WAD) were compared with 50 temporomandibular disorders (TMD) patients and 50 healthy subjects. Endurance was evaluated during unilateral chewing of gum for 5 min when participants reported fatigue and pain. Whereas all healthy subjects completed the task, 1/4 of the TMD and a majority of the WAD patients discontinued the task.[90].

Kurita et al., [91] have tried previously a method to assess chewing ability of patients with several types of jaw dysfunction. For this purpose, a questionnaire was used which included questions about a variety of foods according to size, hardness and stiffness. The study showed that normal controls could take any foods without difficulties, while TMD patients had severe disability with the same foods. The score for chewing ability of the TMD patients was significantly lower than that of the normal controls. In another report, the score of the chewing ability before and after treatment of TMD was compared and found that successfully treated patients showed a significant increase of the score [92]. Tzakis et al., also found positive effect of treatment on the masticatory function [93].

Conclusion

In conclusion, this review shows that product characteristics and to a lesser extent the amount of saliva affect the chewing process. Hard and dry products require more chewing cycles and longer time in mouth until swallowing for sufficient breakdown to take place and for enough saliva to be added to form a coherent bolus safe for swallowing. Masticatory performance is significantly influenced by dental state and bite force. A significant reduction of masticatory function is observed after the loss of teeth. However, the chewing performance can be improved by a dental prosthesis specially when supported by implants. Temporomandibular joint disorders also influence chewing behaviour; though future research should be undertaken, since there are few studies in the literature.

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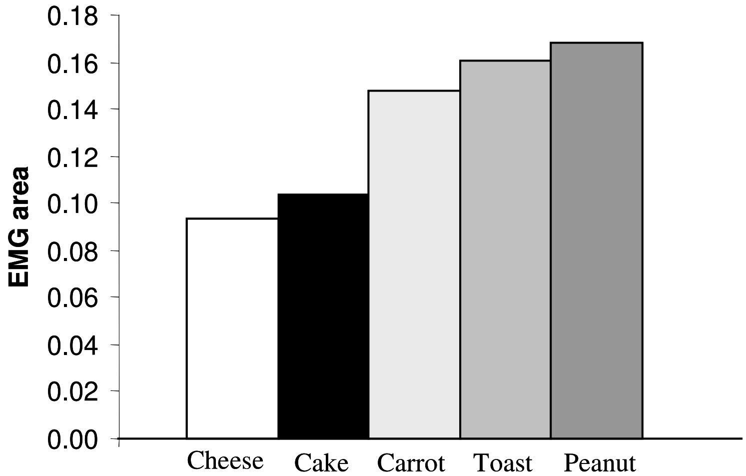

Figure 1: Food distribution according to EMG area

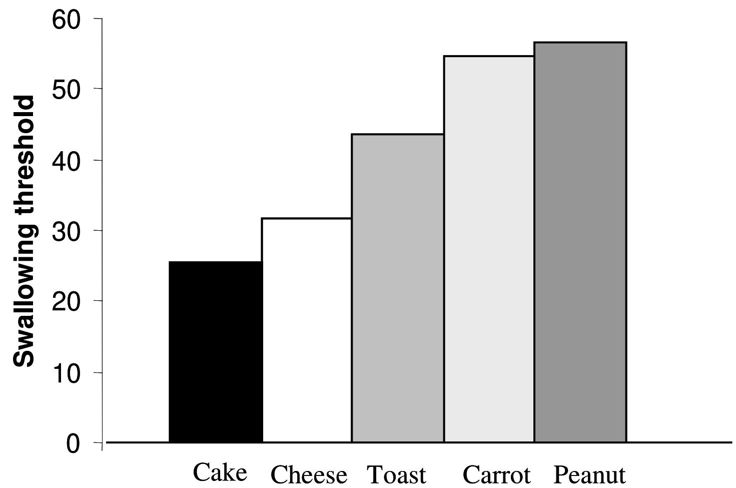

Figure 2: Food distribution according to the number of chewing cycles until swallowing (swallowing threshold)

Effects of Added Fluids on Chewing and Swallowing

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ABSTRACT

The production of sufficient saliva is indispensable for good chewing. Recent research has demonstrated that salivary flow rate has little influence on the swallowing threshold. We examined the hypothesis that adding fluid to a food will influence chewing physiology. Twenty subjects chewed on melba toast, cake, carrot, peanut and Gouda cheese. In addition they chewed on these foods after we added different volumes of water, artificial saliva containing mucins, or a solution of α-amylase. We measured jaw muscle activity, the number of cycles until swallowing, and cycle duration. The additional fluids significantly lowered muscle activity and swallowing threshold for melba, cake and peanut. The effect of the mucins and α-amylase in the solutions was limited. Doubling the volume of tap water had a larger effect. Adding fluid facilitates the chewing of dry foods (melba, cake), but does not influence the chewing of fatty (cheese) and wet products (carrot).

INTRODUCTION

Chewing is the first step in the process of digestion and is meant to prepare the food for swallowing and further processing in the digestive system. During chewing, the food bolus or food particles are reduced in size. The water in the saliva moistens the food particles, whereas the salivary mucins bind masticated food into a coherent and slippery bolus that can be easily swallowed (Pedersen *et al.*, 2002). The urge to swallow can be triggered by a threshold level in both food particle size and lubrication of the food bolus (Hutchings and Lillford, 1988; Prinz and Lucas, 1995; Prinz and Lucas, 1997).

Large differences exist among subjects in both masticatory performance (Julien *et al.*, 1996; Fontijn-Tekamp *et al.*, 2004) and salivary flow rate (Watanabe and Dawes, 1988; Mackie and Pangborn, 1990; Gavião *et al.*, 2004; Engelen *et al.*, 2005). However, these differences are not or only very weakly correlated with the number of chewing strokes needed to prepare the food for swallowing (Fontijn-Tekamp *et al.*, 2004; Engelen *et al.*, 2005). Thus, a subject with a good masticatory performance does not necessarily swallow food at a smaller number of chewing strokes than a subject with a less good masticatory performance. As a consequence good chewers would, on average, swallow finer food particles than bad chewers. Furthermore, a subject with a relatively high salivary flow rate does not necessarily swallow food after less chewing cycles than a subject with less saliva (Engelen *et al.*, 2005). This means that subjects with high salivary flow rates are used to swallow better moistened food. Previous work in our laboratory has shown that there was also no relationship between a subject's salivary flow rate and sensory ratings (Engelen *et al.*, 2003). A subject with a larger salivary flow rate during eating did not rate food differently from a subject with less salivary flow. This finding could indicate that subjects are used to their respective amounts of saliva to such a degree that the differences in sensory ratings between subjects cannot be explained by the inter-individual difference in salivary flow rate. However, an artificial increase of

0.5 ml of saliva significantly influenced the sensory ratings of semisolids (Engelen *et al.*, 2003). While saliva and food have been shown to influence the chewing process, the relationship between amount of saliva and mastication has not been extensively studied (Hector and Linden, 1999). The effect on the chewing process of adding fluid to a solid food is unknown. Therefore, the aim of the present study was to investigate the influence of added fluids (tap water, artificial saliva containing mucins, or a solution of α-amylase) on the chewing physiology: muscle activity, number of chewing strokes until swallowing, and cycle duration. We used different types of food: hard and dry melba toast, soft and dry cake, hard and wet carrot, hard and fat peanut and soft and fat cheese.

MATERIALS & METHODS

Subjects

Twenty healthy subjects (15 females and 5 males) participated in the study. Their age ranged from 19 to 41 years (mean 24.8 ± 6.3 years). They all had natural dentition at least up to the second molars without evident defect of dental structures, periodontal conditions or severe malocclusion. The subjects were divided into a morning and afternoon group based on their availability. Each single subject was, however, always tested on the same time of the day. The Ethics Committee of the University Medical Center Utrecht approved the protocol. Written informed consent was obtained from each subject after a full explanation of the experiment.

Test Foods

We used the following natural foods, all of them with the same calculated volume (8 cm^3): Melba toast (Melba toast, Buitoni, Italy, www.buitoni.com); breakfast cake (Right, Peijnenburg, the Netherlands, www.right.nl); carrot; peanut and Gouda cheese. The physical characteristics of the natural foods (e.g. density, water and fat percentages and yield point) were previously published (Engelen *et al.*, 2005).

Procedure

The subjects chewed on the 5 foods while different volumes of tap water (5 and 10 ml), artificial saliva containing mucins (5 ml of Saliva Orthana - Nycomed, Little Chalfont, UK) and α-amylase solution (5 ml; *bacillus subtilis* - Sigma-Aldrich) were added. As a control the subjects also chewed the foods without added fluid. We chose an α-amylase activity of 200 U/ml, which is of the same magnitude found during chewing (Mackie and Pangborn, 1990). The α-amylase solution was prepared freshly prior to each experiment. The amounts of fluid were based on the saliva secretion in response to food stimulation (Gavião *et al.*, 2004). The liquids were added in the mouth right after the food. During 2 sessions of 1 hour (on 2 separate days) the subjects were presented with duplicates of the samples. All combinations of fluids, volumes and food were administered in random order. The subjects were asked to chew the food in their usual manner until they wanted to swallow. They were free to swallow the food or spit out into a container at the moment of swallowing.

Jaw movement and surface electromyography

During all chewing sequences the jaw gape was measured by recording the position of two infrared light emitting diodes (one on the chin and one on the forehead) with an optical motion analysis system (Northern Digital Optotrak®; www.ndigital.com). The electrical activity of the m.masseteres and the m.temporales anteriores was recorded by means of bipolar electrodes (Blue sensor, Medicotest, Ølstykke, Denmark). The electromyographic (EMG) signals were amplified and sampled at 1500 Hz. Off-line the EMG signals were full-wave rectified and filtered (low pass 35 Hz). We determined the maximum amplitude and the area of the EMG bursts for all chewing cycles for each muscle. Then we summed the values of the left and right masseter and temporalis muscles. We used the movement signal to determine the cycle duration for each chewing cycle and the number of chewing cycles until swallowing.

Statistical Analysis

Repeated-measures analysis of variance (ANOVA SPSS 9.0; SPSS, Chicago, IL, USA) was applied to test the null hypothesis that there would be no statistical difference among the results obtained for the various food types and fluids. Subsequently, contrasts were determined to study the levels of the within-subjects factors (food type and fluid volume). Linear regression was used to determine the change in muscle activity and cycle duration as a function of the chewing cycles. Again we used repeated-measures ANOVA to test the influence of food and fluid on the change of these parameters during chewing. $P < 0.05$ was considered significant.

RESULTS

In the statistical analysis we excluded the results obtained for adding artificial saliva to the food. These results were inconsistent due to an unexpected bad taste of the Saliva Orthana.

Repeated measures ANOVA showed a significant influence on the various physiological parameters of both food type and added fluids (Table 1). Furthermore, we observed a significant statistical interaction between food and fluid, which means that the effect of adding a fluid to a food is not consistent for the different foods. Therefore, we also examined the influence of added fluid on the physiological parameters for each food separately (Table 2). The effect of food and fluid on muscle activity and swallowing threshold is shown in Figure 1.

The type of food had a large significant effect on muscle activity, number of chewing cycles until swallowing, and cycle duration ($p = 0.000$; Table 1). Much more muscle activity was needed for chewing peanut, melba toast, and carrot than for chewing an equivalent volume of cheese or cake (see also Fig. 1). The number of chewing cycles until swallowing cake was significantly lower than for swallowing cheese and melba, whereas cheese and melba were swallowed at a significantly lower number of cycles than peanut and carrot (Table 1 and Fig. 1). The average duration of a chewing cycle was shortest for carrot and peanut, whereas cheese and cake had the longest duration (Table 1).

Adding fluid to the food had a significant influence on muscle activity (melba, peanut, and cake), and on the number of cycles until swallowing (cheese, melba, peanut, and cake; Table 2 and Fig. 1). Less EMG was needed for chewing when a fluid had been added. The type of fluid (water or α-amylase) had no influence on the muscle activity and number of cycles, whereas the volume (5 or 10 ml water) did have a significant influence on muscle activity (melba and peanut) and number of cycles (melba).

During the successive chewing cycles, the muscle activity and duration of a chewing cycle may change due to changes in the food bolus. We found that food type had a significant influence on the change in muscle activity ($p < 0.001$) and on the change in cycle duration ($p < 0.001$), whereas added fluid had no significant influence. The muscle activity significantly decreased for all foods during chewing. The decrease in amplitude of the muscle activity per chewing cycle varied between 0.5 % (peanut and carrot), and about 2 % (melba, cheese and cake; see Fig. 2). The duration of a chewing cycle increased during the chewing process. The increase was significant for all foods except carrot. The increase in cycle duration varied between 0.5 % per cycle (carrot, peanut and melba) up to about 1.5 % per cycle (cheese and cake).

DISCUSSION

We observed large differences in muscle activity (amplitude and burst area), number of cycles until swallowing, and chewing cycle duration for the 5 different foods (Table 1 and Fig. 1). These large differences were caused by the fact that the foods varied largely in hardness (yield point), dryness (percentage water), and fatness (percentage fat) (Engelen *et al.*, 2005). The results we obtained for the number of chewing cycles until swallowing were similar to those found for the same types of foods in that study. Dry and hard products required more chewing cycles before swallowing. More time is needed to fragment the food and to add enough saliva to form a cohesive bolus suitable for swallowing (Anderson *et al.*, 1985). The largest muscle activities were observed for the foods with the highest yield forces (peanut, melba and carrot) which concurs with previous reports (Mathevon *et al.*, 1995; Mioche *et al.*, 1999). The decrease in muscle activity during chewing was largest for cake and melba, which are foods that easily absorb water and are thus softened. Our results concur with previous findings (Lassauzay *et al.*, 2000). The average cycle duration was significantly shorter for carrot and peanut (0.67 s) than for cheese (0.77 s) and cake (0.82 s). Thus, foods that are relatively difficult to chew (peanut and carrot) are chewed at a higher chewing rate than foods that are chewed easily. Our results are in agreement with previous findings on the relationship between chewing rate and food hardness (Ahlgren, 1966; Steiner *et al.*, 1974; Hiiemae *et al.*, 1996). However, it was shown that the hardness of a food did not influence the chewing rate for chewing gum (Anderson *et al.*, 2002) and for silicone rubber (Kohyama *et al.*, 2004). We observed that the duration of a chewing cycle increased during the chewing process. Thus, when the food softens during chewing the cycle duration increases. Similar results were reported for elastic model foods (Lassauzay *et al.*, 2000).

The adding of fluid had a significant effect on muscle activity for melba, cake, and peanut, and on the number of cycles until swallowing for melba, cake, peanut, and cheese (Table 2). In Fig. 1 the influence of both food and fluid on muscle activity and number of chewing cycles is visualized. It is clear from Fig. 1 that the influence of adding fluid is much smaller than the influence of food (see also Table 1). The added fluids had a larger influence on the number of chewing cycles until swallowing than on the muscle activity as can be seen from the F-values in Table 2. The largest effect of fluid on muscle activity and swallowing was observed for melba and cake. This fact is obviously related to the dryness of these foods. The chewing variables related to peanut were also significantly affected despite the fact that peanut has a large fat percentage (about 50 %). Apparently, the additional water facilitates the formation of a swallowable bolus (Pangborn and Lundgren, 1977). Adding fluid had no influence on EMG and number of cycles for carrot. This may be due to the large percentage (90 %) of water in carrot (Engelen *et al.*, 2005). Adding an additional 5 ml of water caused a significant effect in EMG and swallowing threshold for melba and peanut. We did not observe significant differences between water and α-amylase. Apparently, the α-amylase already present in the mouth was sufficient to adequately break down the starch.

In addition to water, one of the contents of saliva is mucins, which cover and protect the oral cavity (Tabak *et al.*, 1982; Levine *et al.*, 1987). Mucins also provide saliva with its lubricative properties and facilitate manipulation, mastication and swallowing (van der Reijden *et al.*, 1993). Because of the properties of mucins, we expected to observe an improvement in chewing and swallowing. Unfortunaletly, we obtained inconsistent results after we added artificial saliva containing mucins to the food. The taste of this solution was experienced as bad by all subjects, which led to a high variance for all parameters. Taste cognition can modify food mastication in the mouth (Neyraud *et al.*, 2005). As taste is a subjective factor, it may induce different responses within different subjects, which may explain the large variance in our results.

The additional fluids significantly lowered muscle activity and swallowing threshold for melba and cake, and less prominent for peanut. Melba and cake are dry products, which require enough saliva to be added to form a coherent bolus safe for swallowing. The chewing of fatty (cheese) and wet (carrot) products was not influenced. The effect of the mucins and α-amylase in the solutions was rather limited. Doubling the volume of tap water had a larger effect than adding α-amylase to the water.

Acknowledgements

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Table 1: Influence of foods and fluids on the physiological parameters

	EMG amplitude (mV)	EMG area (mV.s)	number of cycles until swallowing	cycle duration (s)
food influence	F = 101 p = 0.000	F = 61 p = 0.000	F = 96 p = 0.000	F = 41 p = 0.000
post-hoc test food influence[a,b]	ch = ck <<< me = cr < pe	ch = ck <<< me = cr << pe	ck <<< ch = me <<< pe = cr	cr = pe < me <<< ch = ck
fluid influence	F = 7.0 p = 0.002	F = 12.2 p = 0.000	F = 36 p = 0.000	F = 1.8 p = 0.18
food*fluid interaction	F = 2.3 p = 0.038	F = 3.4 p = 0.004	F = 8.2 p = 0.000	F = 1.7 p = 0.15

[a] ch: cheese; ck: cake; me: melba toast; cr: carrot; pe: peanut
[b] =: p>0.05; <: p<0.05; <<: p<0.01; <<<: p<0.001

Table 2: F- and p-values of effects of added fluids on the physiological parameters for each of the 5 foods

	EMG amplitude	EMG area	number of cycles until swallowing	cycle duration
carrot fluid influence	F = 0.9 p = 0.45	F = 1.7 p = 0.20	F = 0.5 p = 0.70	F = 4.0 p = 0.020
carrot post-hoc test[a,b]	wo = w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5	wo < w5 = w10 w5 = a5
cheese fluid influence	F = 1.5 p = 0.25	F = 0.4 p = 0.68	F = 7.5 p = 0.001	F = 3.0 p = 0.061
cheese post-hoc test	wo = w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5	wo>> w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5
melba fluid influence	F = 7.2 p = 0.001	F = 10.8 p = 0.000	F = 46.9 p = 0.000	F = 0.8 p = 0.46
melba post-hoc test	wo >> w5 = w10 w5 = a5	wo >> w5 > w10 w5 = a5	wo >>> w5 > w10 w5 = a5	wo = w5 = w10 w5 = a5
peanut fluid influence	F = 2.1 p = 0.11	F = 6.3 p = 0.002	F = 7.1 p = 0.001	F = 5.9 p = 0.002
peanut post-hoc test	wo = w5 = w10 w5 = a5	wo > w5 > w10 w5 = a5	wo >> w5 = w10 w5 = a5	wo = w5 = w10 w10 > a5
breakfast cake fluid influence	F = 3.2 p = 0.037	F = 5.0 p = 0.009	F = 18.0 p = 0.000	F = 0.7 p = 0.54
breakfast cake post-hoc test	wo > w5 = w10 w5 = a5	wo >> w5 = w10 w5 = a5	wo >> w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5

[a] wo: without fluid; w5: 5 ml water; w10: 10 ml water; a5: 5 ml α-amylase solution
[b] =: p>0.05; <: p<0.05; <<: p<0.01; <<<: p<0.001

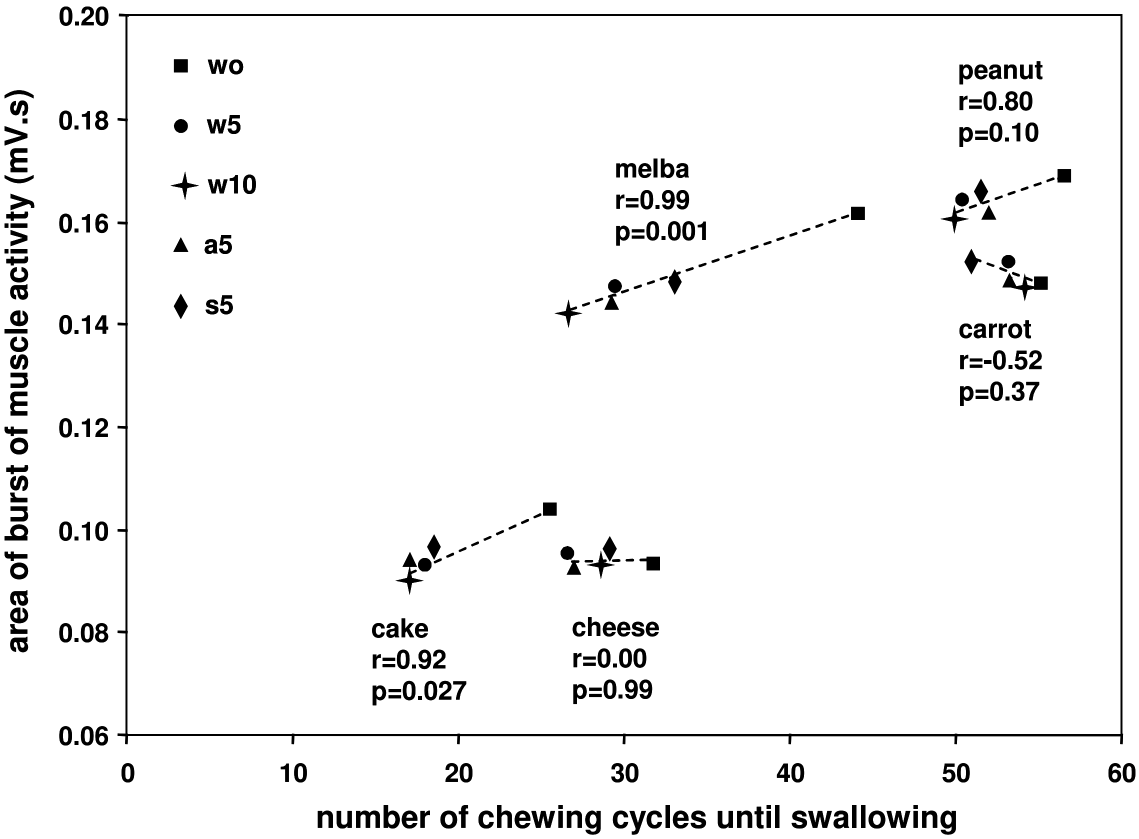

Figure 1: Mean values for muscle activity (EMG) area and number of chewing cycles for the different foods and fluids.

wo: without solution; w5: water 5 ml; w10: water 10 ml; a5: α-amylase solution 5ml; s5: artificial saliva 5 ml

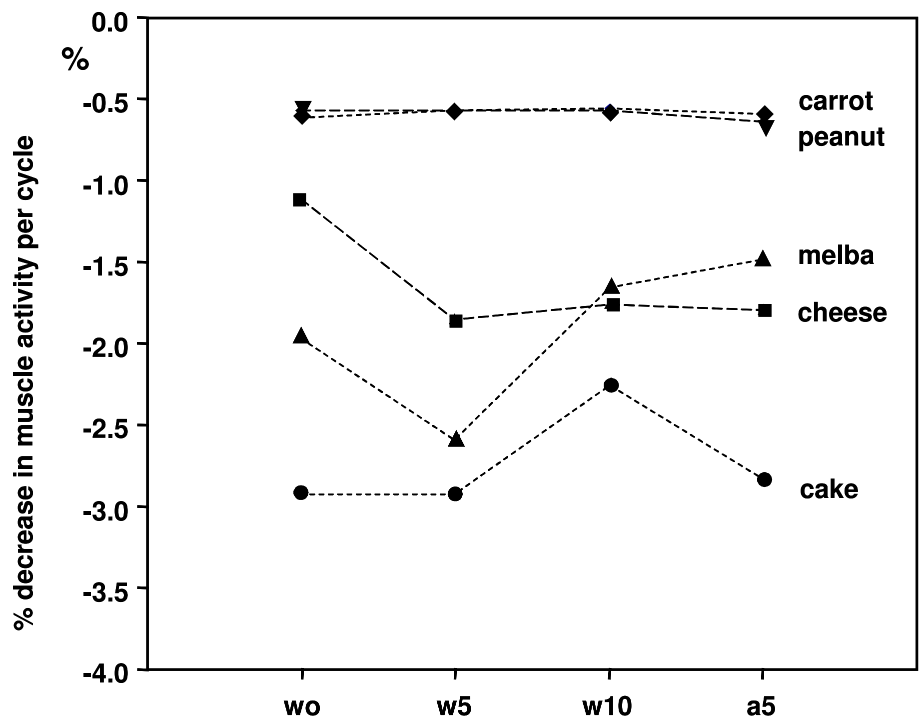

Figure 2: Percentage decrease in muscle activity per cycle during chewing for the different foods and fluids.

wo: without solution; w5: water 5 ml; w10: water 10 ml; a5: α-amylase solution 5ml

Effects of added fluids in the perception of natural solid food

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Running head: Added Fluids and Oral Perception

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Abstract

PEREIRA, L.J., M.B.D. GAVIÃO, R.A. DE WIJK AND A. VAN DER BILT. Effects of added fluids in the perception of natural solid food. PHYSIOL BEHAV 00(0) 000-000, 2006. The production of sufficient saliva is indispensable for good chewing. Recent research has demonstrated that salivary flow rate has little influence on the swallowing threshold. We examined the hypothesis that adding fluid to a food will influence the chewing process. Twenty healthy subjects chewed on melba toast, breakfast cake, carrot, peanut and Gouda cheese. In addition they chewed on these foods after we added different volumes of tap water, artificial saliva containing mucins, or a solution of α-amylase. We measured jaw muscle activity and the number of cycles until swallowing. Furthermore, we obtained VAS scores for texture and sound attributes for all foods and fluid conditions. The additional fluids significantly lowered muscle activity and swallowing threshold for melba, cake and peanut. The effect of the mucins and α-amylase in the solutions was rather limited. Doubling the volume of tap water had a larger effect. Several texture and sound attributes of melba, cake and peanut were also significantly affected by the additional fluids. For melba, cake, and peanut we observed significant correlations between the physiology parameters and several attributes for the various fluid conditions. This indicates that the added fluid affects both the physiology (muscle activity and number of cycles) and the sensory perception of a number of texture and sound attributes. Adding fluid facilitates the chewing of dry foods (melba, cake), but does not influence the chewing of fatty (cheese) and wet products (carrot).

Key words: saliva, swallow, mastication, oral physiology, sensory attributes

Introduction

Chewing is the first step in the process of digestion. The food is prepared for swallowing and further processing in the digestive system. During chewing, the food particles are reduced in size, while saliva is produced to moisten and lubricate the food so that it can be swallowed. The initiation of swallowing, which is voluntary, has been thought to depend on separate thresholds for food particle size and for particle lubrication [1]. Taste and texture of the food are perceived and have their influence on the chewing process.

Large differences exist among subjects in salivary flow rate [2-5]. However, these differences are not or only very weakly correlated with the number of chewing strokes needed to prepare the food for swallowing [5]. Thus, a subject with a relatively high salivary flow rate does not necessarily swallow food after less chewing cycles than a subject with less saliva. Apparently, subjects with high salivary flow rates are used to swallow better moistened food than subjects with lower salivary flow rates. It has been shown that there was also no relationship between a subject's salivary flow rate and sensory ratings [6]. Thus, a subject with a relatively large salivary flow rate during eating did not rate food differently from a subject with less salivary flow. This finding could indicate that subjects are used to their amount of saliva to such a degree that the differences in sensory ratings between subjects cannot be explained by the inter-individual difference in salivary flow rate. However, an artificial increase in the amount of saliva significantly influenced the sensory ratings of a semisolid [6]. Similarly, a subjects own amylase activity did not affect their sensory ratings [6], whereas an artificial increase or decrease of amylase activity did affect ratings [7]. The effect of adding fluid to a solid food on the sensory ratings is unknown. Adding fluid to a dry food may decrease the salivary flow during chewing as was observed in rabbits eating dry pellets when water was injected [8]. However, the reduction in salivary flow will probably be neglectable compared to the additional amount of water. Food properties may be modified by the additional fluid, which may lead to changes in chewing force, mandibular jaw movements, and number of chewing cycles to prepare the food for swallowing. It can be hypothesized that an artificial increase in the amount of saliva mixing with food could also influence the perception of the food. The mucins may help to form a smooth food bolus that can be easier swallowed, whereas the α-amylase may help break down the starch in the food.

The aim of the present study was to investigate the influence of adding fluids to various solid foods on physiology parameters of the chewing process, and on the perception of the food. We used tap water, artificial saliva containing mucins, or a solution of α-amylase. Five foods differing largely in characteristics were used: melba (hard and dry), cake (soft and dry), carrot (hard and wet), peanut (hard and fat), and cheese (soft and fat). We determined muscle activity, jaw movement, and the number of chewing cycles needed to prepare the food for swallowing. Furthermore, we obtained VAS scores for texture and sound attributes. We studied the relationship between oral physiology and sensory perception for all foods and all fluid conditions.

Material and Methods

Subjects

Twenty healthy subjects (15 females and 5 males) participated in the study. Their age ranged from 19 to 41 years (mean 24.8 ± 6.3 years). They all had natural dentition at least up to the second molars without evident defect of dental structures, periodontal conditions or severe malocclusion. The subjects were divided into a morning and afternoon group based on their availability. Each single subject was, however, always tested on the same time of the day. The Ethics Committee of the University Medical Center Utrecht approved the protocol. Written informed consent was obtained from each subject after a full explanation of the experiment.

Test Foods

We used the following natural foods, all of them with the same calculated volume (8 cm^3): melba toast (melba toast, Buitoni, Italy, www.buitoni.com); breakfast cake (Right, Peijnenburg, the Netherlands, www.right.nl); carrot; peanut and Gouda cheese. The physical characteristics of the natural foods (e.g. density, water and fat percentages and yield point) were previously published [5].

Procedure

The subjects chewed on the 5 foods while different volumes of tap water (5 and 10 ml), artificial saliva containing mucins (5 ml of Saliva Orthana - Nycomed, Little Chalfont, UK) and α-amylase solution (5 ml; *bacillus subtilis* - Sigma-Aldrich) were added. As a control the subjects also chewed the foods without added fluid. We chose an α-amylase activity of

200 U/ml, which is of the same magnitude found during chewing [3]. The α-amylase solution was prepared freshly prior to each experiment. The amounts of fluid were based on the saliva secretion in response to food stimulation [4]. The liquids were added in the mouth right after the food. During 2 sessions of 1 hour (on 2 separate days) the subjects were presented with duplicates of the samples. All combinations of fluids, volumes and food were administered in random order. Prior to the experiments, foods were brought to room temperature (20 ^{o}C). The subjects were asked to chew the food in their usual manner until they wanted to swallow. They were free to swallow the food or spit out into a container at the moment of swallowing. In between the samples, subjects were allowed to sip water.

Jaw movement and surface electromyography

During all chewing sequences the jaw gape was measured by recording the position of two infrared light emitting diodes (one on the chin and one on the forehead) with an optical motion analysis system (Northern Digital Optotrak®; www.ndigital.com). The electrical activity of the m.masseteres and the m.temporales anteriores was recorded by means of bipolar electrodes (Blue sensor, Medicotest, Ølstykke, Denmark; diameter 6 mm; inter-electrode distance 18 mm). The maximum deflection location of the electrodes was determined by palpation while the subjects intermittently clenched their teeth. An electrode on the forehead served as a ground reference. The electromyographic (EMG) signals were amplified and sampled at 1500 Hz. Off-line the EMG signals were full-wave rectified and filtered (low pass 35 Hz). We determined the area of the EMG bursts for all chewing cycles for each muscle. Then the values obtained for the right and left masseter and temporalis muscles were summed. Furthermore, we determined the number of chewing cycles until swallowing from the movement signal.

Attributes

In a third session we evaluated attributes. Twenty-two texture and sound representative attributes were selected from a set of 64 attributes developed for the sensory profiling of crispy and crunchy foods [9]. In this session the subjects received one sample of each combination of food and fluids used in the previous 2 sessions, and also the food without solution. The order of the samples was randomized. Texture and sound attributes were rated for all food-fluid combinations on a 100-mm VAS scale, ranging from "very little" to "very much". The attributes were divided into "at first bite" and "during chewing" categories. The definitions of the attributes are given in Table 1. Prior to the distribution of the samples, the subjects received an explanation of all the items. During the experiment, they were encouraged to look at the attributes descriptions to reinforce the understanding of each item.

Statistical Analysis

Repeated-measures analysis of variance (ANOVA SPSS 9.0; SPSS, Chicago, IL, USA) was applied to test the null hypothesis that there would be no statistical difference among the results obtained for the various food types and fluid conditions. Subsequently, contrasts were determined to study the levels of the within-subjects factor (fluid condition). A possible relationship between physiology parameters and attributes was tested using Pearson's correlation coefficients. $P < 0.05$ was considered significant. The relationships between sensory attributes, instrumental measurements and foods were summarized in biplots using Principal Component Analysis (PCA) (Unscrambler, Camo Inc.) using panel averaged data. PCA facilitates identification of attribute synonyms and covariate attributes.

Results

In the statistical analysis we excluded the results obtained for adding artificial saliva to the food. These results were inconsistent for both physiology and attributes due to an unexpected bad taste of the Saliva Orthana.

Physiology

An example of the jaw movement and rectified muscle activity of a subject chewing on melba toast is given in Fig. 1. In this Figure we plotted the results for the 4 fluid conditions: without additional fluid, with 5 and 10 ml of water, and with 5 ml of an α-amylase solution. A clear effect of the addition of fluid on the number of chewing cycles until swallowing can be seen from this Figure.

The group averages of muscle activity and number of chewing cycles until swallowing for the various fluid conditions are plotted in Fig. 2. Repeated measures ANOVA showed that the type of food had a large significant effect on muscle activity ($F(4,95)=61$; $p=0.000$), and number of chewing cycles until swallowing ($F(4,95)=96$; $p=0.000$). Adding a fluid to the food had a significant influence on muscle activity (melba, peanut, and cake), and on the number of cycles until swallowing (cheese, melba, peanut, and cake; Table 2). Less EMG was needed for chewing when a fluid had been added. The type of fluid (water or α-amylase) had no influence on the muscle activity and number of cycles, whereas the volume (5 or 10 ml water) did have a significant influence on muscle activity (melba and peanut) and number of cycles (melba). The muscle activity needed for chewing carrot and cheese was not influenced by the added fluids.

Attributes

The PCA bi-plot (Fig. 3) summarises the effects of food type and added fluid on texture and sound attributes and on physiology parameters. The first sensory dimension runs from sticky to hard and snappy and the second from dry and crumbly to tough and springy. Two of the foods, peanut and cake, relate primarily to the first dimension, with cake being sticky and peanut hard and snappy. The other three foods also relate to the second dimension, with cheese being sticky and springy, carrot being tough and snappy, and melba being dry and snappy. As can be seen the differences among the foods are much larger than the differences caused by the fluids added to a food.

According to repeated measures ANOVA analysis the type of food had a large significant effect on all attributes with F-values ranging from 10 up to 200. Some of the attributes were also significantly influenced by adding fluid to the food (Table 3). For carrot, cheese and peanut a few attributes only were significantly influenced by the additional fluid. Cheese was perceived as having less resistance and peanut as less gooey after adding fluid (Table 3). Adding fluid to the food had more influence for melba and cake. The VAS scores for a number of attributes were lower after fluid had been added to these foods.

Correlations among physiology and attributes

Significant correlations were observed between physiology parameters (emg and number of chewing cycle until swallowing) and attributes, as obtained for the various fluid conditions, for melba, peanut, and cake (Table 4). An example of the relationship between physiology and attributes is shown in Fig. 4. In this Figure we plotted the perceived duration of chewing as a function of the number of chewing cycles needed to prepare the food for swallowing. For this combination of parameters we observed a significant correlation for cake only. The correlation over all 25 data points (5 foods and 5 fluids) was highly significant ($r=0.97$; $p=0.000$; Fig. 4). Similar high correlations were found for all other combinations of physiology parameters and attributes. The physiology parameters, emg and number of cycles, were significantly correlated for melba ($r=0.99$; $p=0.001$) and cake ($r=0.92$; $p=0.03$).

Discussion

The present study investigated the influence of adding fluid (water, α-amylase or artificial saliva with mucins) to a food on physiology parameters and on the perception of different types of natural solid food.

In addition to water, one of the contents of saliva is mucins, which cover and protect the oral cavity [10,11]. Mucins also provide saliva with its lubricative properties and facilitate manipulation, mastication and swallowing [12]. Because of the properties of mucins, we expected to observe an improvement in chewing, swallowing, and texture and sound attributes. Unfortunaletly, we obtained inconsistent results after we added artificial saliva containing mucins to the food. The taste of this solution was experienced as bad by all subjects, which led to a high variance for all parameters. Taste cognition can modify food mastication in the mouth [13]. As taste is a subjective factor, it may induce different responses within different subjects, which may explain the large variance in our results.

Physiology parameters

The type of food had a large significant effect on the physiological parameters (muscle activity, and number of chewing cycles until swallowing). This is caused by the fact that the foods we used, varied largely in hardness (yield point), dryness (percentage water), and fatness (percentage fat). An overview of the food characteristics was published recently [5]. The results we obtained for the number of chewing cycles until swallowing were similar to those found for the same types of foods in that study. Dry and hard products required more chewing cycles before the food was swallowed, which is in agreement with a previous study [14]. More time is needed to fragment the food and to add enough saliva to form a cohesive bolus suitable for swallowing [8]. The largest muscle activities were observed for the foods with the highest yield forces (peanut, melba and carrot). Similar influences of food characteristics on mastication have been reported previously [15-20].

Adding a fluid to the food caused a significant effect on muscle activity (melba, cake, and peanut), and on the number of cycles until swallowing (melba, cake, peanut, and cheese; Table 2). Fig. 2 shows the effect of adding fluid to the food for muscle activity and for the number of cycles until swallowing. Decreases in EMG and number of cycles after adding fluid to the food can be clearly seen from this Figure. Furthermore, Fig. 2 illustrates that the influence of adding a fluid to the food is much smaller than the influence of food type. The large effect of food type is caused by the large differences in the characteristics of the foods we used, which is in accordance with previous research. The effect of added fluid to the food was largest for melba and cake (Table 2). This is obviously related to the dryness of these foods. The chewing variables related to peanut were also significantly affected despite the fact that peanut has a large fat percentage (about 50 %). Apparently, the additional water facilitates the formation of a swallowable bolus [21]. Adding fluid had no influence on EMG and number of cycles for carrot. This may be due to the large percentage (90 %) of water in carrot [5]. Adding an additional 5 ml of water caused a significant effect in EMG and swallowing threshold for melba and peanut. We did not observe significant differences between water and α-amylase. Similar results were found for additional α-amylase solutions in custard deserts [6]. Apparently, the α-amylase already present in the mouth was sufficient to adequately break down the starch.

Attributes

We observed significant effects of adding a fluid to the food for a number of attributes (Table 3). Melba had the largest number of attributes which were significantly affected by adding the fluid. Subjects scored attributes related to drying, sound, and hard much lower after fluid had been added to the melba. Melba has a very low percentage of water [5]. Due to the additional fluid melba is apparently softened much faster causing lower scores for both hardness and sound. Cake, a dry food, also scored significantly lower on the attribute drying. Furthermore, cake was perceived as less sticky and tough after adding a fluid. Peanut scored much lower on gooey. The added fluid made it less pulpy during chewing. Similar results were found for custard deserts where added fluids decreased the thickness, creaminess and fatty sensations [6]. The sensory rating of cheese were hardly influenced by the fluids. Cheese only scored lower on bite force. Cheese has a high percentage of fat (31

%) and water (35 %), which may prevent additional water to play an important role. No significant influences on attributes were observed for carrot. This is probably caused by the fact that carrot has a large percentage (90 %) of water and carrot particles do not easily mix with water. As for the physiology parameters we did not observe significant differences between water and α-amylase.

Correlations between physiology and attributes

We observed significant correlations among physiology parameters and attributes for melba, peanut and cake (Table 4). Thus, adding a fluid had an effect on both physiology and attributes for these foods. Again melba showed the most significant influence of added fluid as can be seen from the large number of attributes correlating with emg and number of chewing cycles until swallowing. The largest correlation was observed between the absorbation of saliva (drying) and the physiology parameters muscle activity and number of chewing cycles. Thus, adding a fluid to melba decreases both the perceived dryness and the physiological effort to chew this food. For cake we observed the highest correlations for the attributes drying, tough (effort to chew the food), and duration and the physiology parameter number of chewing cycles. For peanut only a few significant correlations were observed, which were related to the attributes hardness and type of sound during chewing and the physiology parameter muscle activity used to chew this food. Added fluid thus reduces both perceived hardness of peanut and muscle activity needed to chew it. In Fig. 4 an example is shown depicting the correlation between the perceived duration of chewing and the measured number of chewing cycles. For this combination of attribute and physiology parameter we observed a significant correlation for cake only. A highly significant correlation (r = 0.97) was observed between perceived duration and number of chewing cycles when all foods and fluid conditions were considered. Similar high correlations were observed for all other combinations of physiology parameters and attributes. Apparently the variation in food properties was so large that both physiology and attributes were significantly influenced.

We may conclude that adding fluid to a food influences both oral physiology parameters and texture and sound perception for all foods except carrot. Muscle activity, the number of chewing cycles needed to prepare the food for swallowing and various texture and sound attributes were significantly lowered after adding a fluid to the food. The largest effects in both physiology and perception were observed for melba, which is a hard and dry food. Adding fluid facilitates the chewing of dry foods (melba, cake), but does not influence the chewing of fatty (cheese) and wet products (carrot). It may be speculated that all food-liquid combinations are processed to a similar consistency and viscosity of the food bolus that is ready to be swallowed. Adding water or an α-amylase solution to the food had a similar influence on both perception and oral physiology. Apparently, the α-amylase already present in the mouth was sufficient to adequately break down the starch.

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Table 1. List of the attributes evaluated and descriptions

Attribute		Definition
At first Bite		
f-bfo	Bite force	Resistance, force you have to exert to bite, not necessarily hard
f-har	Hard	Resistance, with sound, snaps. Bite force needed
f-crm	Crumbly	Small pieces in the mouth
f-spl	Splinters	Sharp pieces in the mouth
f-sti	Sticky	Sticks to the teeth
f-sou	Sound	Amount and loudness of sound
f-tso	Type of sound	From low to high pitch (confer the musical scale do-re-mi-fa-sol-la-si-do)
f-snp	Snapping	Loud, sharp, short sound
f-crn	Crunchy	High pitched sound, light sound, longer sounding
During chewing		
d-har	Hard	Resistance, with sound, snaps. Chewing force needed
d-air	Airy	Not compact
d-spr	Springy(elastic/rubbery)	Regains original shape
d-dry	Drying	Saliva absorbing
d-dis	Disintegrating	Mainly the crust, pieces in the mouth
d-spl	Splinters	Sharp pieces in the mouth
d-tou	Tough	Combination of bite force and duration of chewing. Chewing efficiency is too low
d-goo	Gooey	By chewing it forms a pap in the mouth. Pulpy
d-dur	Duration of chewing	Time you are working to rid it (until you can swallow)
d-sou	Sound	Amount and loudness of sound
d-tso	Type of sound	From low to high pitchb(confer the musical scale do-re-mi-fa-sol-la-si-do)
d-snp	Snapping	Loud, sharp, short sound
d-crn	crunchy	High pitched sound, light sound, longer sounding

Table 2. Influence of added fluids: F(3,76)- and p-values of effects of 4 fluid conditions on the physiological parameters for each of the 5 foods.

	muscle activity (EMG)	number of cycles until swallowing
carrot fluid influence	F = 1.7 p = 0.20	F = 0.5 p = 0.70
carrot post-hoc test[*, #]	wo = w5 = w10 w5 = a5	wo = w5 = w10 w5 = a5
cheese fluid influence	F = 0.4 p = 0.68	F = 7.5 p = 0.001
cheese post-hoc test	wo = w5 = w10 w5 = a5	wo>> w5 = w10 w5 = a5
melba fluid influence	F = 10.8 p = 0.000	F = 46.9 p = 0.000
melba post-hoc test	wo >> w5 > w10 w5 = a5	wo >>> w5 > w10 w5 = a5
peanut fluid influence	F = 6.3 p = 0.002	F = 7.1 p = 0.001
peanut post-hoc test	wo > w5 > w10 w5 = a5	wo >> w5 = w10 w5 = a5
breakfast cake fluid influence	F = 5.0 p = 0.009	F = 18.0 p = 0.000
breakfast cake post-hoc test	wo >> w5 = w10 w5 = a5	wo >> w5 = w10 w5 = a5

[*] wo: without fluid; w5: 5 ml water; w10: 10 ml water; a5: 5 ml α-amylase solution
[#] =: p>0.05; <: p<0.05; <<: p<0.01; <<<: p<0.001

Table 3. Influence of fluids on the texture and sound attributes of the various foods. Attributes are listed only when influence of fluid is significant with $p < 0.05$ (tested with repeated measures ANOVA). VAS scores for the attributes were lower after fluid was added to the food.

food	attributes [*]	F(3,76)	p	post-hoc test [#, **]	
cheese	fb bite force	5.4	0.008	wo = w5 > w10	w5 = a5
melba	fb bite force	4.7	0.018	wo = w5 > w10	w5 = a5
	fb hard	8.1	0.001	wo = w5 > w10	w5 = a5
	fb crumbly	5.3	0.004	wo > w5 = w10	w5 = a5
	fb splinters	8.2	0.000	wo > w5 > w10	w5 = a5
	fb sound	9.5	0.000	wo >> w5 > w10	w5 = a5
	fb type of sound	6.3	0.003	wo = w5 >> w10	w5 = a5
	fb crunchy	3.2	0.039	wo = w5 > w10	w5 = a5
	dc drying	26.9	0.000	wo >>> w5 = w10	w5 = a5
	dc duration	3.4	0.025	wo > w5 = w10	w5 = a5
	dc crunchy	3.2	0.040	wo = w5 = w10	w5 = a5
peanut	dc gooey	8.0	0.001	wo = w5 > w10	w5 = a5
cake	fb sticky	3.1	0.050	wo = w5 > w10	w5 = a5
	dc drying	11	0.000	wo >> w5 = w10	w5 = a5
	dc tough	3.0	0.046	wo > w5 = w10	w5 = a5
	dc duration	4.2	0.023	wo > w5 > w10	w5 = a5

[*] fb: first bite; dc: during chewing

[#] wo: without fluid; w5: 5 ml water; w10: 10 ml water; a5: 5 ml α-amylase solution

[**] =: p>0.05; <: p<0.05; <<: p<0.01; <<<: p<0.001

Table 4. Pearson correlations between physiology parameters (emg and number of chewing cycles to prepare the food for swallowing) and the texture and sound attributes for the fluid conditions. Correlations are listed only when the correlations are significant with $p < 0.05$.

food	physiology	attributes*	r	p	physiology	attributes[a]	r	p
melba	emg	fb splinter	0.95	0.01	number	fb splinter	0.92	0.03
	emg	fb sound	0.93	0.02	number	fb sound	0.88	0.05
	emg	dc hard	0.90	0.04	number	dc hard	0.87	0.05
	emg	dc drying	0.96	0.01	number	dc drying	0.98	0.003
	emg	dc sound	0.92	0.03	number	dc sound	0.92	0.03
	emg	dc crunchy	0.88	0.05	number	dc crunchy	0.88	0.05
peanut	emg	fb hard	0.88	0.05				
	emg	fb splinter	0.90	0.04				
	emg	dc type of sound	0.92	0.03				
cake	emg	dc springy	0.88	0.05	number	dc springy	0.95	0.01
	emg	dc duration	0.91	0.03	number	dc drying	0.98	0.003
					number	dc tough	0.98	0.003
					number	dc gooey	0.97	0.007
					number	dc duration	0.96	0.01
					number	dc crunchy	0.89	0.05

* fb: first bite; dc: during chewing

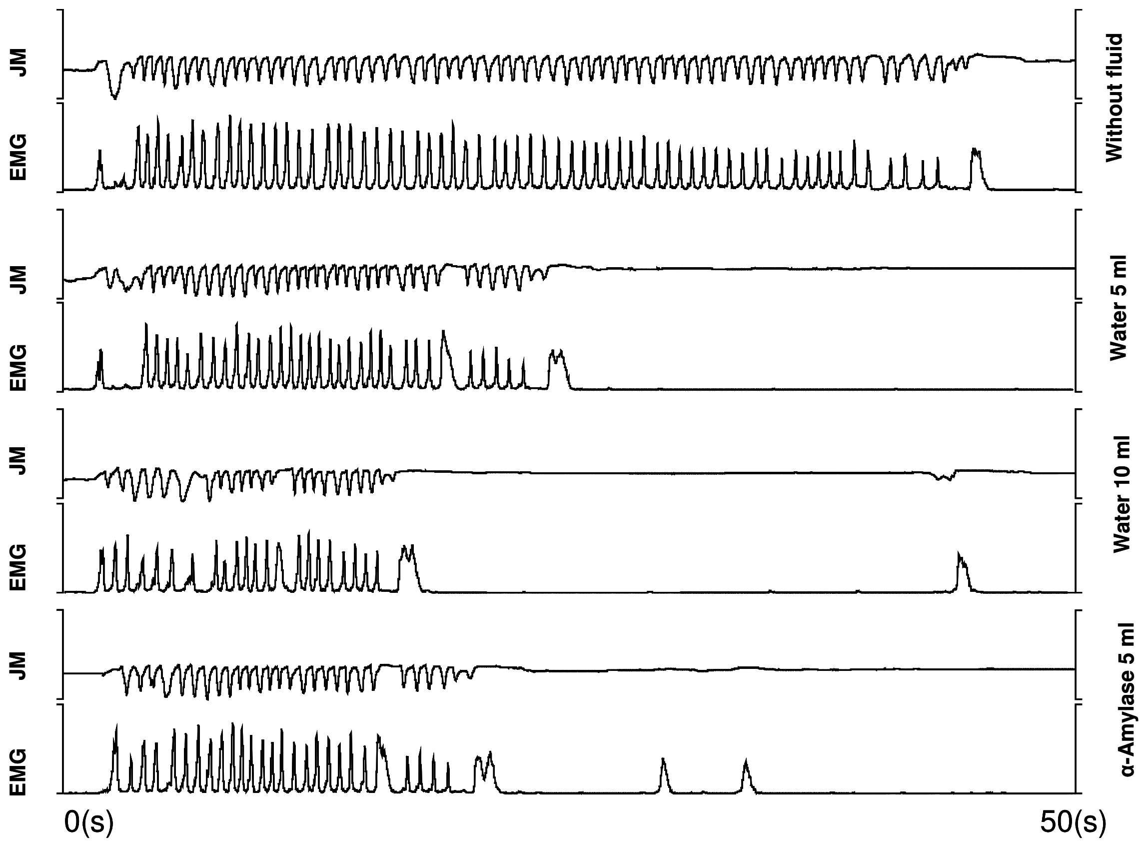

Fig. 1 Jaw movement (JM) and rectified muscle activity (EMG) of a subject chewing melba toast for the various fluid conditions.

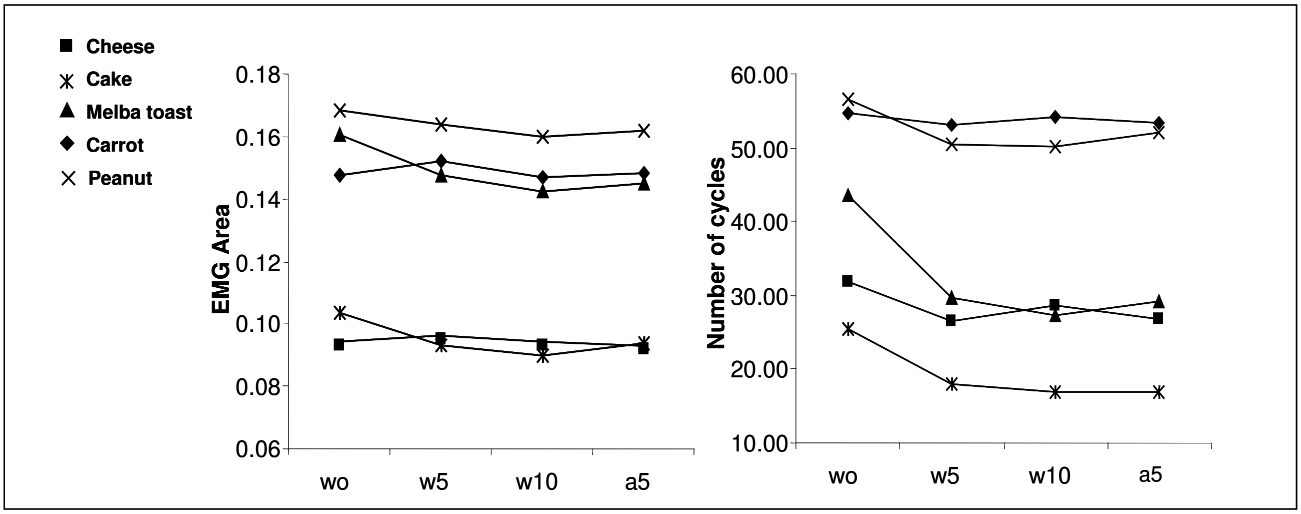

Fig. 2 Muscle activity (EMG area of bursts) and number of chewing cycles until swallowing for the various foods and fluid conditions: without fluid (wo), with 5 ml water (w5), with 10 ml water (w10), and with 5 ml of α-amylase solution (a5).

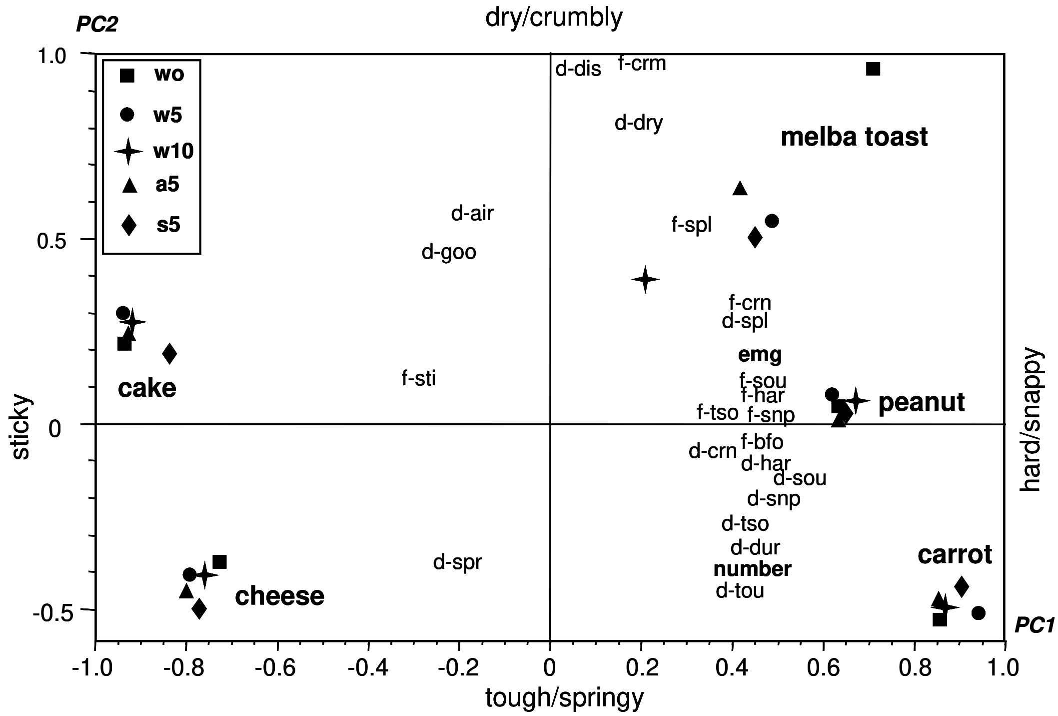

Fig. 3. Bi-plot of principal components analysis depicting texture and sound attributes, physiology parameters, and foods with various fluid conditions. The abbreviations of attributes are explained in Table 1. Physiology parameters: emg: area of EMG burst; number: number of chewing cycles until swallowing. PC1 (sticky – hard/snappy) explains 75% of the variance, PC2 (dry/crumbly - tough/springy) explains 15%.

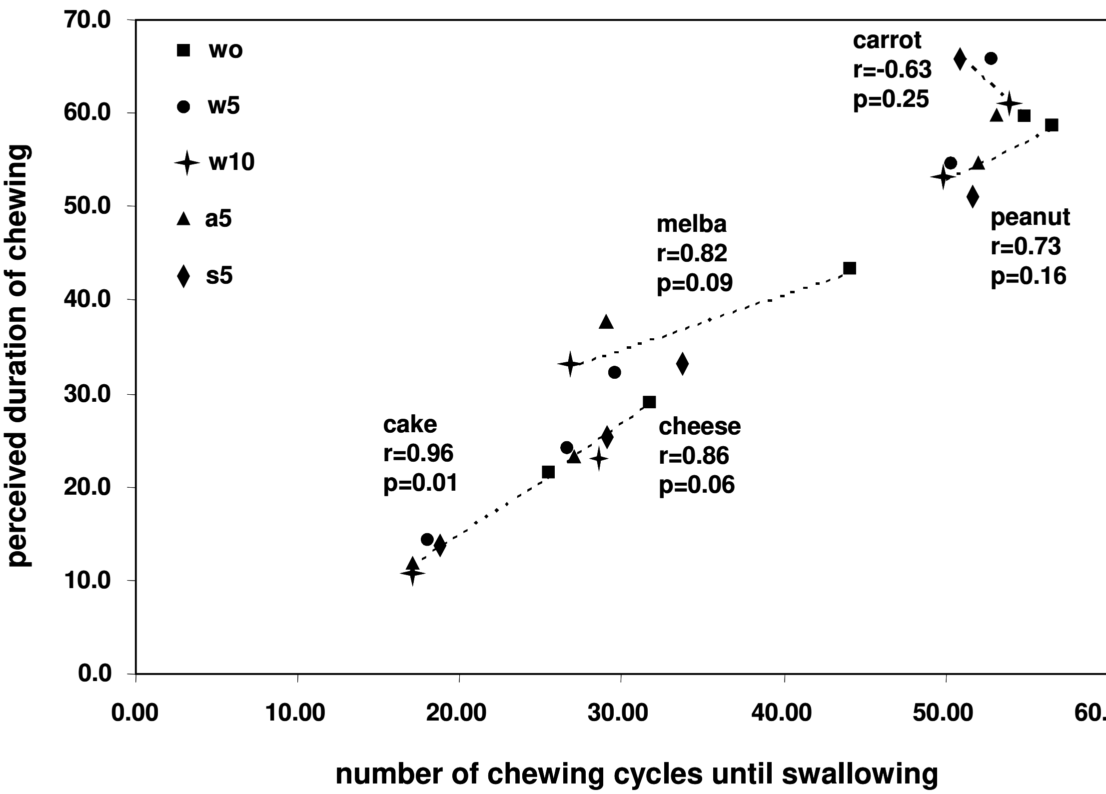

Fig. 4 Perceived duration of chewing versus the number of chewing cycles until swallowing for the different foods and fluids. The correlation over all 25 data points (foods and fluids) is highly significant: r=0.97; p=0.000

wo: without solution; w5: water 5 ml; w10: water 10 ml; a5: α-amylase solution 5ml; s5: artificial saliva 5 ml

CONCLUSÔES GERAIS

A presente pesquisa visou avaliar as características morfológicas e funcionais do sistema mastigatório de crianças, adolescentes e adultos saudáveis e portadores de sinais e sintomas de Disfunção Temporomandibular. A partir dos resultados apresentados as seguintes conclusões foram estabelecidas:

- Espessura dos músculos mastigatórios está correlacionada com peso e altura corporais, indicando que o desenvolvimento desses músculos acompanha o desenvolvimento corporal.
- Influência de sinais e sintomas de disfunção temporomandibular na espessura muscular de adolescentes tende a ser leve, devido à baixa severidade dos sinais clínicos.
- Não houve correlação significativa entre espessura dos músculos mastigatórios masséter e temporal anterior e atividade elétrica em adolescentes com e sem sinais e sintomas de disfunção temporomandibular.
- Houve uma correlação negativa entre a espessura do músculo masséter e o Índice CMI, sugerindo que os sinais clínicos de disfunção temporomandibular estão envolvidos em diminuição da função mastigatória, causando conseqüentemente diminuição na espessura deste músculo.
- Indivíduos com diferentes morfologias faciais apresentam também diferenças na espessura dos músculos masseter e temporal anterior.
- Não houve associação entre um padrão facial específico e sinais e sintomas de disfunção temporomandibular, apesar de ter ocorrido uma ligação entre sobressaliência aumentada e padrão de face longa com a presença de sinais e sintomas.

- A força de mordida aumentou significativamente da dentição mista para a dentição permanente.

- As variáveis corporais peso e altura só se correlacionaram com a força de mordida máxima na dentição permanente, sugerindo que o aumento da idade e conseqüentemente a influência dos hormônios sexuais contribuem para o aumento na força de mordida na dentição permanente.

- A presença de sinais e sintomas de disfunção temporomandibular, especialmente aqueles relacionados a sensibilidade muscular em meninas foram de influência para a diminuição na força de mordida neste grupo.

- Na avaliação da influência de fluidos (relacionados a saliva) adicionais na atividade mastigatória e no limiar de deglutição, foi observado que estes beneficiaram a mastigação de alimentos secos (bolo e torrada Melba) e menos pronunciadamente para alimentos com maior área de superfície (amendoim). Alimentos gordurosos ou úmidos não foram significativamente alterados.

- Soluções contendo mucinas ou enzima α-amilase não proporcionaram efeitos mais pronunciados que o acréscimo de água na avaliação fisiológica e sensorial da mastigação. Entretanto, o aumento no volume de água (10 ml) apresentou efeitos mais significativos.

- Os efeitos mais pronunciados dos fluidos adicionais na fisiologia e percepção mastigatória foram encontrados para a torrada Melba devido a sua baixa porcentagem de água. Sugere-se que os alimentos são mastigados de forma a atingirem uma determinada consistência que é percebida como segura para a deglutição.

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ANEXOS

Termo de Consentimento Livre e Esclarecido

MENOR:____

As informações contidas neste prontuário visam firmar acordo por escrito, mediante o qual o responsável pelo menor, objeto de pesquisa, autoriza sua participação, com pleno conhecimento da natureza dos procedimentos e riscos a que se submeterá o paciente, com capacidade de livre arbítrio e sem qualquer coação.

I - TÍTULO DO TRABALHO EXPERIMENTAL:

AVALIAÇÃO DA FORÇA DE MORDIDA, DA ATIVIDADE ELETROMIOGRÁFICA E DA ESPESSURA DOS MÚSCULOS MASSETER E TEMPORAL ANTERIOR EM ADOLESCENTES COM DISFUNÇÃO TEMPOROMANDIBULAR

Responsáveis: Maria Beatriz Duarte Gavião, Luciano José Pereira

II - OBJETIVOS

O objetivo deste estudo será a avaliar os músculos da mastigação de indivíduos jovens, de 12 a 18 anos portadores ou não de sinais e sintomas de disfunção da ATM (desarranjo da articulação entre a mandíbula e o crânio; e dos músculos associados), através da ultra-sonografia para verificação da espessura dos músculos, da eletromiografia para verificação da atividade muscular, da força de mordida e radiografias cefalométricas para determinação do padrão de crescimento facial.

III - JUSTIFICATIVA

Este trabalho justifica-se considerando que o estudo da disfunção da ATM em pacientes jovens pode ser importante em determinar precocemente os problemas que predispõem a anormalidades do crescimento, dor muscular ou disfunção mandibular na fase adulta. Também é importante salientar que existem poucos trabalhos na literatura relativos à avaliação das estruturas e da função da ATM em adolescentes, fase em que o crescimento e o desenvolvimento adequado estão se concretizando. O diagnóstico precoce de alterações permitirá intervenções que poderão influir na função adequada do sistema estomatognático. A realização de exames em grupo de pacientes assintomáticos decorre do fato de muitos destes serem portadores de alterações morfo-funcionais da articulação e não apresentarem qualquer sintomatologia clínica. Por isso, a realização de exames diagnósticos em adolescentes não portadores de sinais e sintomas pode ser interessante para prevenção de futuras complicações decorrentes de alterações nas estruturas articulares. (Kircos et al, 1987)

IV - PROCEDIMENTOS DO EXPERIMENTO

AMOSTRA - serão examinados adolescentes de ambos os sexos, na faixa etária de 12 a 18 anos de idade, os quais freqüentam escolas da rede estadual e municipal de Piracicaba e serão selecionados 40, após a devida autorização do responsável para a sua participação na pesquisa, e do próprio paciente, quando maior de idade, de acordo com os seguintes procedimentos:

ANAMNESE - através de entrevista com o responsável e o paciente, verificando-se: histórico médico, histórico dental e hábitos.

EXAME CLÍNICO BUCAL - os instrumentos utilizados serão os de uso rotineiro na clínica (pinça, sonda exploradora e espelho bucal), além do refletor e seringa tríplice; verificar-se-á as condições dos lábios, gengiva, língua, palato, freios labial e lingual e dentes presentes.

EXAME CLÍNICO DENTÁRIO

- número de dentes presentes
- dentes precocemente perdidos
- anomalias de forma (dentes com aparência diferente do normal), número (falta de dentes ou dentes a mais) e estrutura (defeitos na formação dos tecidos que compõem o dente)
- tratamento ortodôntico (uso de aparelhos para correção de dentes malposicionados)

EXAME MORFOLÓGICO DA OCLUSÃO

- relação ântero-posterior dos molares – classificação do engrenamento dos molares (dentes encaixados durante a mordida): na posição normal; molar superior à frente da posição normal ou atrás da posição normal.
- relação vestíbulo-lingual dos molares – classificação do engrenamento dos molares (dentes encaixados durante a mordida): posição normal; molares superiores por dentro dos inferiores
- relação ântero-posterior dos caninos – caninos na posição normal, encaixado à frente ou atrás da posição normal
- relação vestíbulo-lingual dos caninos – posição normal; canino superior encaixado por dentro do canino inferior
- relação dos incisivos - dentes da frente superiores na posição normal ; encaixados por dentro dos dentes inferiores
- situação de desgaste dos dentes - nenhum desgaste, desgaste pequeno, desgaste profundo (HANSSON & NILNER, 1975)
- sobressaliência: dentes da frente superiores muito inclinados para fora;

- sobremordida: dentes da frente superiores cobrindo grande parte dos dentes inferiores quando a boca está fechada - uso de instrumento de medida digital

EXAME FUNCIONAL DA OCLUSÃO

- desvio do queixo quando abre a boca - será traçada uma linha vertical na superfície visível dos dentes da frente superiores e inferiores, observando se na abertura e no fechamento há maior deslocamento do queixo para um dos lados ou desvio da linha média;
- abertura bucal máxima - com o uso de um aparelho de leitura digital, o sujeito abrirá a boca o máximo possível e será feita a medida correspondente;
- empurrar o queixo para frente o máximo possível – pedimos para o sujeito empurrar o queixo o máximo possível para frente, e com o auxílio de uma régua milimetrada, faz-se a medida do espaço entre o dente da frente superior e o inferior;
- empurrar o queixo para a direita e esquerda - com o uso de marcações da relação da linha média inferior com o arco superior durante o movimento, faz-se a medida com o aparelho de leitura digital;
- presença de interferências na mordida entre os dentes no lado para o qual se desloca o queixo ou no lado oposto, com o uso de papel carbono e espelho clínico bucal.

SINTOMAS SUBJETIVOS

- dores de cabeça
- dor ou algum problema de ouvido
- dor nos músculos do pescoço
- dor nos músculos do ombro
- dor na mandíbula (ou na articulação entre a mandíbula e o crânio)
- dor durante a mastigação
- dor quando abre a boca
- a dor será considerada como sintoma de disfunção (doença) se for relatada freqüência de pelo menos uma vez por semana e estar presente pelo menos durante os últimos 3 meses.
- dificuldade para engolir
- barulho quando abre a boca
- apertamento ou ranger dos dentes

SINAIS CLÍNICOS:

- dor à palpação na articulação entre a mandíbula e o crânio: será considerada quando o paciente relatar desconforto e/ou o examinador observar reflexo nas pálpebras;

- dor à palpação muscular – na região das têmporas, na região da articulação próximo ao ouvido, na face, no pescoco, quando o paciente relatar desconforto e/ou o examinador observar reflexo nas pálpebras;
- dor durante a mastigação de material teste artificial – Parafilm M
- dor quando abre a boca
- ruídos quando abre e fecha a boca: estalo ou barulho similar a presença de areia na articulação- palpação e auscultação com estetoscópio colocado sobre as articulações à frente da orelha direita e esquerda, durante o movimento de máxima abertura e fechamento;
- movimento da mandíbula, isto é, se ocorre de maneira desigual - palpação na articulação e realização de movimentos de abertura e fechamento, confirmando portanto, o desvio mandibular.
- movimentos mandibulares restritos:
- quando não conseguir empurrar o queixo para frente e para os lados mais que 5 mm
- abertura bucal – menor que 35 mm

Após a avaliação de todos os exames a amostra será classificada em 2 grupos, a saber:
GRUPO I - 20 crianças sem sinal e sintoma de disfunção (alteração da função) 10 do sexo feminino e 10 do sexo masculino
GRUPO II - 20 crianças apresentando pelo menos 1 sinal e 1 sintoma de disfunção (alteração da função) 10 do sexo feminino e 10 do sexo masculino

V - ULTRA-SONOGRAFIA

Para a ultra-sonografia utilizaremos o equipamento de ultra-som digital Just Vision 200, da Toshiba Corporation, Japão, com transdutor Linear 38 mm (parte do aparelho que encosta na pele), banda-larga de 10 MHz. Serão feitos exames das ultra-sonografias dos músculos masseter (bochecha) e temporal anterior (região das têmporas, lateralmente à testa) nas posições mandibulares de repouso e contração máxima (mordendo). As imagens dos músculos obtidas nas respectivas posições serão mensuradas em milímetros, com as ferramentas disponíveis no programa do equipamento. Os participantes permanecerão sentados eretos, com as cabeças em posição natural. Os registros serão repetidos duas vezes com intervalo de 5 minutos.

VI - ELETROMIOGRAFIA

Para o registro da atividade elétrica dos músculos será utilizado aparelho eletromiográfico registrado no Os dados serão coletados no Laboratório de Eletromiografia do Departamento de Odontopediatria – FOP – UNICAMP, que constitui ambiente adequado, permitindo a coleta do sinal eletromiográfico de melhor qualidade. Além disso, o ambiente para tomada eletromiográfica não proporcionará estímulo sonoro, visual ou tátil que possa elevar o nível de tensão do paciente. A duração do exame será de aproximadamente 30 minutos para cada sujeito.

Durante o experimento, o adolescente permanecerá sentado confortavelmente em uma cadeira, com as costas completamente apoiadas no encosto e será solicitado que a mesmo permaneça com a coluna ereta, olhos abertos, pés apoiados no solo, braços apoiados sobre as pernas.

Para a correta fixação dos eletrodos (dispositivos colados à pele) nos músculos, será realizada a prévia limpeza da pele e dos eletrodos com álcool etílico a 96° GL e, os mesmos serão fixados na pele com o uso de uma fita adesiva. Para a colocação dos eletrodos será realizada a prova de função para cada músculo.

O sinal eletromiográfico será captado:

- Em contração voluntária máxima bilateral incentivada pelo experimentador (mordida máxima), tendo o material *Parafilm* posicionado entre os dentes bilateralmente. O comando verbal adequado será dado para manter o máximo de força possível, durante 5 segundos, sendo que o voluntário repetirá a contração por três vezes, com intervalo de 30 segundo entre cada coleta.

Todos os dados serão anotados em ficha clínica de uso rotineiro da Clínica de Odontologia Infantil – FOP – Unicamp, adaptada a essa pesquisa e, os valores encontrados em todas as etapas da pesquisa para todos os adolescentes serão tabulados de forma a facilitar a visualização dos mesmos.

VII - FORÇA DE MORDIDA

O exame de análise da força de mordida será realizado solicitando que o adolescente morda sobre um tubo de fibra reforçado contendo ar de 10mm de espessura conectado a um sensor de pressão. O sistema será conectado ao computador, que informa o força realizada.

O voluntário receberá instruções para, durante a coleta, ficar sentado com a cabeça em posição relaxada. O tubo transmissor será posicionado entre os dentes. Os sujeitos serão devidamente treinados, antes da coleta efetiva, para se conseguir a correta realização da mordida do tubo transmissor. Após a verificação do aprendizado, será solicitado ao voluntário que morda, com o máximo de força possível, sem causar desconforto, durante 05 segundos, incentivado por comando verbal do pesquisador. Esse procedimento será repetido 03 vezes, com intervalo de 30 segundos, aproximadamente, entre cada mordida.

VIII - DETERMINAÇÃO DO PADRÃO FACIAL

As radiografias cefalométricas serão obtidas com os indivíduos em posição de mordida e elaboradas seguindo as normas da disciplina de Radiologia da FOP-UNICAMP. Os traçados serão realizados através da demarcação de pontos para a obtenção do padrão de crescimento facial.

IX - PESO E ALTURA CORPORAIS

Os sujeitos serão pesados em balança comum. A massa corporal, expressa pela proporção peso/altura, serão correlacionadas com a força de mordida, com atividade eletromiográfica e espessura dos músculos a serem avaliados.

X - RISCOS ESPERADOS

Os procedimentos realizados não oferecem riscos uma vez que os exames clínicos intra-bucal e extra-bucal seguem os passos da rotina clínica, não havendo nenhum método invasivo na obtenção dos dados, utilizando-se instrumental e materiais adequados. Quanto ao exame de ultra-sonografia, este não oferece riscos já que é uma técnica indolor e rotineiramente utilizada no acompanhamento de exames pré-natais, para observação do desenvolvimento fetal (Close *et al* –1995). A radiografia cefalométrica não oferece riscos para os pacientes tendo em vista que são exames diagnósticos amplamente utilizados em odontologia e serão realizadas com o menor tempo de radiação possível. Todas as normas de assepsia em relação ao manuseio dos equipamentos utilizados serão observadas. Garante-se que os examinadores estarão devidamente paramentados, quando do preparo dos equipamentos, em ambiente adequado. Antes do experimento propriamente dito, cada adolescente receberá todas as informações sobre os procedimentos, sendo orientado de modo que realize os testes adequadamente.

XI - INFORMAÇÕES

O responsável pelo menor tem a garantia de que receberá respostas a qualquer pergunta ou esclarecimento sobre qualquer dúvida à cerca dos procedimentos, riscos, benefícios, empregados neste documento e outros assuntos relacionados à pesquisa. Também serão dadas informações sobre o diagnóstico das alterações detectadas, o prognóstico e o plano de tratamento que deverá ser instituído, de acordo com os critérios adotados pela disciplina de Odontopediatria do Departamento de Odontologia Infantil da FOP-UNICAMP.

XII - RETIRADA DO CONSENTIMENTO

O responsável pelo menor tem a liberdade de retirar seu consentimento a qualquer momento e deixar de participar do estudo, sem qualquer prejuízo ao atendimento odontológico a que o adolescente está sendo ou será submetido na Clínica de Odontologia Infantil e na Clínica do Curso de Especialização em Odontopediatria, da Faculdade de Odontologia de Piracicaba -UNICAMP.

XIII - CONSENTIMENTO PÓS-INFORMAÇÃO

PACIENTE MENOR DE IDADE

Eu____, responsável pelo menor ____, certifico que, tendo lido as informações acima e suficientemente esclarecido (a) de todos os itens, estou plenamente de acordo com a realização do experimento. Assim, eu autorizo a execução do trabalho de pesquisa exposto acima.

Piracicaba, _____ de ________________ de 200_.

NOME (legível)____RG________________

ASSINATURA____

PACIENTE MAIOR DE IDADE

Eu____, certifico que, tendo lido as informações acima e suficientemente esclarecido (a) de todos os itens, estou plenamente de acordo com a realização do experimento. Assim, eu autorizo a execução do trabalho de pesquisa exposto acima.

Piracicaba, _____ de ________________ de 200_.

NOME (legível)____RG________________

ASSINATURA____

ATENÇÃO: A sua participação em qualquer tipo de pesquisa é voluntária. Em caso de dúvida quanto aos seus direitos, escreva para o Comitê de Ética em Pesquisa da FOP-UNICAMP. Endereço - Av. Limeira, 901 - CEP/FOP - 13414-900 - Piracicaba – SP.

No caso de qualquer emergência entrar em contato com os pesquisadores responsáveis no Departamento de Odontologia Infantil/Odontopediatria da FOP-UNICAMP. Telefones de contato: 0XX 19 3412 5368 e 0XX 19 3412 5287

UNICAMP

COMITÊ DE ÉTICA EM PESQUISA

UNIVERSIDADE ESTADUAL DE CAMPINAS

FACULDADE DE ODONTOLOGIA DE PIRACICABA

CERTIFICADO

Certificamos que o Projeto de pesquisa intitulado "Avaliação da força de mordida, da atividade eletromiográfica e da espessura dos músculos masseter e temporal anterior em adolescentes com disfunção temporomandibular", sob o protocolo nº **081/2003**, do Pesquisador ***LUCIANO JOSÉ PEREIRA***, sob a responsabilidade da Profa. Dra. **MARIA BEATRIZ DUARTE GAVIÃO**, está de acordo com a Resolução 196/96 do Conselho Nacional de Saúde/MS, de 10/10/96, tendo sido aprovado pelo Comitê de Ética em Pesquisa – FOP.

Piracicaba, 06 de agosto de 2003

We certify that the research project with title "Bite force, electromyographic and thicness evaluation of the masseter and anterior temporalis muscles in adolescents with temporomandibular dysfunction", protocol nº **081/2003**, by Researcher ***LUCIANO JOSÉ PEREIRA***, responsibility by Prof. Dr. **MARIA BEATRIZ DUARTE GAVIÃO,** is in agreement with the Resolution 196/96 from National Committee of Health/Health Department (BR) and was approved by the Ethical Committee in Research at the Piracicaba Dentistry School/UNICAMP (State University of Campinas).

Piracicaba, SP, Brazil, August 08 2003

Prof. Dr. Pedro Luiz Rosalen
Secretário
CEP/FOP/UNICAMP

Prof. Dr. Antonio Bento Alves de Moraes
Coordenador
CEP/FOP/UNICAMP

Termo de Consentimento
Experimentos realizados no estágio de doutorando no exterior

Utrecht, 9 mei 2005

Geachte mevrouw / heer,

U heeft aangegeven dat u belangstelling heeft voor deelname aan een wetenschappelijk onderzoek. Dit onderzoek wordt uitgevoerd door de Vakgroep Bijzondere Tandheelkunde (UMC Utrecht). In deze brief treft u informatie aan over het onderzoek.

Om wat voor onderzoek gaat het?
Het onderzoek bestudeert de invloed van de behandeling op het kauwvermogen en op de bijtkracht.

Verloop van het onderzoek
Tijdens het onderzoek, dat circa 60 minuten duurt, worden er 3 testjes gedaan. Eerst bepalen we de maximale bijtkracht door u zo hard mogelijk op een bijtkrachtmeter te laten klemmen. Vervolgens bepalen we uw kauwvermogen. Hiertoe kauwt u enige tijd op een kunstvoedsel.
Tijdens het kauwen brengen we uw kaakbewegingen en kauwspieractiviteit in beeld. Voor dit laatste onderdeel plakken we 2 kleine lampjes en 9 kleine elektrodes op uw gezicht. Voor een goed huidcontact met de elektrodes is het nodig dat de huid schoongemaakt wordt. Dit doen wij met alcohol.

Uw rechten bij deelname aan het onderzoek
Uw deelname aan dit onderzoek is geheel vrijwillig. U kunt op elk moment van het onderzoek beslissen om af te zien van verdere deelname, zelfs zonder opgaaf van redenen. De verzamelde informatie is strikt vertrouwelijk en wordt anoniem verwerkt.
Indien u niet tevreden bent over de wijze waarop het onderzoek is verlopen, kunt u uw ongenoegen kenbaar maken aan één van de medewerkers van het onderzoek.
Mocht er schade optreden als gevolg van deelname aan het onderzoek, dan zal dit worden vergoed middels een daartoe afgesloten verzekering.

Tot slot
Heeft u nog vragen over het onderzoek, dan kunt u altijd aan één van onze medewerkers om nadere uitleg vragen. Ook tijdens ons onderzoek staat vragen vrij. Namen en telefoonnummers van de medewerkers vindt u aan het eind van deze brief.
Voor het onderzoek is het noodzakelijk dat u de Instemmingsverklaring ondertekent.

Met vriendelijke groeten,

drs. L. Pereira
(tel. 030-2533373)

dr. A. van der Bilt
(tel. 030 - 2533096)

Instemmingsverklaring

Hierbij verklaart mevrouw/mijnheer*

Naam : ______________________________

Adres : ______________________________

Postcode/Woonplaats : ______________________________

Telefoonnummer : ______________________________

Geboortedatum : ______________________________

zowel mondeling als schriftelijk op de hoogte te zijn gebracht van het onderzoeksproject "Orale functie".

Het doel van het onderzoek is mij uiteengezet. Ik verklaar hierbij vrijwillig te willen deelnemen aan het onderzoek, met het recht op elk moment het onderzoek te mogen beëindigen zonder opgaaf van redenen.

Datum: : ______________

Plaats: : ______________

Handtekening : ______________

Esta mensagem foi escrita com um conjunto de caracteres diferente do seu. Se ela não for mostrada corretamente clique aqui *para abrí-la em uma nova janela.*

----- Original Message -----
From: Dr. Marc Saadia
To: mbgaviao@fop.unicamp.br
Sent: Saturday, December 24, 2005 1:23 PM
Subject: manuscript

The Journal of

Clinical Pediatric Dentistry

December, 2005

Dear Dr.Gaviao:

We are pleased to inform you that we received this interesting article entitled:

Ultasonography and electromyography of masticatory muscles in a group of adolescents with signs and symptoms of TMD

This work has been received as an original article to be reviewed by our Editorial Committee. We ask you to please send us an e-mail to this address drmarcsaadia@gmail.com

in 4 to 8 weeks in order to let you know if your work has been accepted to be published in our Journal.

We thank you for your preference to our Journal.

Sincerely,

Dr. Marc Saadia

Editor-in-Chief

European Journal of
Orthodontics

Flat 20, 49 Hallam Street
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Professor M B Duarte Gavião
Faculdade de Odontologia de Piracicaba/UNICAMP
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Brazil

30 August 2005

Dear Professor Duarte Gavião

MUSCLE THICKNESS, BITE FORCE AND CRANIOFACIAL DIMENSIONS IN ADOLESCENTS WITH SIGNS AND SYMPTOMS OF TEMPOROMANDIBULAR DYSFUNCTION, Pereira, Duarte Gavião, Bonjardim, Castelo and van der Bilt

Thank you for sending us the above manuscript for possible publication in the European Journal of Orthodontics. Your paper is being sent to independent referees for assessment and when their reports are received we shall write further.

Your article has been allocated the reference (122/05) and I should be grateful if you would quote this on all correspondence.

Yours sincerely

Susan Austin (Mrs)
Editorial Assistant

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Preview

From: oral.sciences@odontologi.gu.se

To: mbgaviao@fop.unicamp.br

Cc:

Subject: European Journal of Oral Sciences - Manuscript ID EOS-2242-MAN-05

Body: 16-Aug-2005

Dear Prof. Gaviao:

Thank you for submitting your manuscript entitled "Bite force and its correlation with clinical signs of temporomandibular dysfunction in mixed and permanent dentition" to the European Journal of Oral Sciences. It has been successfully submitted online and is presently being given full consideration.

Your manuscript ID is EOS-2242-MAN-05.

Please refer to the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your street address or e-mail address, please log in to Manuscript Central at http://mc.manuscriptcentral.com/eos and edit your user information as appropriate.

We will contact you again as soon as we have the necessary information for an editorial decision. You can also view the status of your manuscript at any time by checking your Author Center after logging in to http://mc.manuscriptcentral.com/eos .

Sincerely,

European Journal of Oral Sciences Editorial Office

Date Sent: 16-Aug-2005

Date: Mon, 31 Oct 2005 16:14:11 +0100
From: Folke Lagerlöf <Folke.Lagerlof@ki.se>
Subject: Acta Odontologica Scandinavica 1095
To: a.vanderbilt@med.uu.nl
X-Mailer: Microsoft Office Outlook, Build 11.0.6353
Thread-Index: AcXeLL0Hbnq9hn/7SWu5sA6g13fDfw==
Original-recipient: rfc822;a.vanderbilt@med.uu.nl

Dear Dr van der Bilt,

Today I have received your manuscript entitled "Mastication: influence of saliva, food, dentition, muscle force and temporomandibular disorders. Review Article " to be considered for publication in *Acta Odontologica Scandinavica*.

The typescript, in accordance with the usual formalities, has been dispatched to the reviewers and a further communication will be sent to you in due course.

Yours Sincerely,

Folke Lagerlöf
Editor-in-Chief
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Detailed Status Information

Manuscript #	05-0458
Current Revision #	0
Submission Date	2005-11-03
Current Stage	Under Consideration
Title	Effects of Added Fluids on Chewing and Swallowing
Running Title	Effect of Added Fluids on Chewing
Category	Clinical
Manuscript Comment	abstract: 149 words manuscript and abstract: 2477 words references: 25 tables: 2 figures: 2 appendices: 0
Corresponding Author	Andries van der Bilt (University Medical Center Utrecht)
Contributing Authors	Luciano J. Pereira , Maria Beatriz Gaviao , Lina Engelen
Abstract	The production of sufficient saliva is indispensable for good chewing. Recent research has demonstrated that salivary flow rate has little influence on the swallowing threshold. We examined the hypothesis that adding fluid to a food will influence chewing physiology. Twenty subjects chewed on melba toast, cake, carrot, peanut and Gouda cheese. In addition they chewed on these foods after we added different volumes of water, artificial saliva containing mucins, or a solution of α- amylase. We measured jaw muscle activity, the number of cycles until swallowing, and cycle duration. The additional fluids significantly lowered muscle activity and swallowing threshold for melba, cake and peanut. The effect of the mucins and α- amylase in the solutions was limited. Doubling the volume of tap water had a larger effect. Adding fluid facilitates the chewing of dry foods (melba, cake), but does not influence the chewing of fatty (cheese) and wet products (carrot).
Associate Editor	Assigned
Key Words	saliva, mastication, swallow, food, muscle activity

Stage	Start Date
Under Consideration	2005-11-03
	2005-11-03
Submission	2005-11-03

Date: Tue, 01 Nov 2005 12:14:43 +0000
From: Physiology & Behavior <physiolbehav@psychiatry.uc.edu>
Subject: Submission Confirmation
To: andries.vanderbilt@med.uu.nl
X-OriginalArrivalTime: 01 Nov 2005 12:14:43.0699 (UTC)
FILETIME=[D7A52430:01C5DEDD]
Original-recipient: rfc822;andries.vanderbilt@med.uu.nl

Dear Andries,

Your submission entitled "Effects of added fluids in the perception of natural solid food" has been received by Physiology & Behavior

You may check on the progress of your paper by logging on to the Elsevier Editorial System as an author. The URL is http://ees.elsevier.com/phb/.

Your manuscript will be given a reference number once an Editor has been assigned.

Thank you for submitting your work to this journal.

Kind regards,

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