Clin Oral Invest (2017) 21:159–166
DOI 10.1007/s00784-016-1768-5

ORIGINAL ARTICLE

Factors associated with masticatory performance among preschool children

Maria Eliza Consolação Soares[1] · **Maria Letícia Ramos-Jorge**[1] · **Bruna Mota de Alencar**[1] · **Leandro Silva Marques**[1] · **Luciano José Pereira**[2] · **Joana Ramos-Jorge**[1]

Received: 16 November 2015 / Accepted: 22 February 2016 / Published online: 1 March 2016

Abstract

Objective The aim of the present study was to evaluate the influence of the body mass index (BMI), food consistency, and oral problems on masticatory performance among preschool children.

Methods A cross-sectional study was conducted with a sample composed of 279 children between 3 and 5 years of age allocated to three groups (underweight, ideal weight, and overweight) based on the BMI. Moreover, eating habits, malocclusion, breathing type, masticatory units, and untreated dental caries were investigated. For the evaluation of masticatory performance, the masticatory function test (Optocal) and Rosin-Rammler equation were used for the determination of median size (X50) of shredded food particles for each child. Data analysis involved the description of the frequency of the variables as well as both simple and multiple linear regression analysis.

Results A larger median participle size was associated with a greater number of cavitated teeth ($p < 0.001$), greater frequency of the daily ingestion of liquid foods ($p = 0.001$), and a higher BMI ($p < 0001$). A greater number of masticatory units ($p < 0.001$), older age ($p = 0.007$), and greater frequency of the daily intake of solid foods ($p = 0.019$) were factors that contributed to a smaller median food particle size.

Conclusion BMI, number of cavitated teeth, number of masticatory units, child's age, and food consistency exerted an influence on masticatory performance among preschool children.

Clinical relevance Mastication is important for craniofacial growth and development. Thus, dentists should know the factors that affect the masticatory performance among children with primary teeth.

Keywords Mastication · Pediatric obesity · Body mass index · Dental caries · Malocclusion · Preschool

✉ Maria Eliza Consolação Soares
lisadtna@yahoo.com.br

[1] Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal dos Vales do Jequitinhonha e Mucuri, Rua da Glória, 187, Diamantina, MG 39.100-000, Brazil

[2] Department of Physiology and Pharmacology, School of Medicine, Universidade Federal de Lavras, Lavras, Brazil

Introduction

Mastication is the first step in the digestive process, the aim of which is to break down foods for swallowing [1]. In this process, smaller food particles swallowed lead to greater absorption of nutrients [2]. Chewing function may measured by masticatory performance, in which the size of food particles after a standardized number of cycles is determined [3]. The shredding of foods during mastication can be influenced by anatomic and physiologic characteristics, such as malocclusion [4], area of occlusal and proximal contact [5], masticatory units [6], and age [7]. Studies have recently investigated the influence of factors, such as dental caries [8] and the body mass index (BMI) [9, 10] on masticatory performance.

A Brazilian study conducted with 30 preschool children found the anterior and/or posterior crossbite exerted a negative influence on masticatory performance [11]. A study conducted in Japan found no influence of a child's weight, height, and bite force on masticatory performance among 24 preschool children [12].

In Brazil, the prevalence of childhood obesity is approximately 14.1 % [13]. Children with overweight and obesity consume a large amount of snacks rich in saturated fat, which are generally easy to chew [14]. Consequently, the masticatory muscles are not sufficiently required to shred foods with greater consistency [15]. This consistency can determine whether a child will acquire satisfactory mastication pattern and muscle strength [9]. Thus, investigating masticatory performance among children in the primary dentition phase is important, as the three years prior to the mixed dentition phase are fundamental to the occurrence of physiologic changes in growth and adaptability, establishing habits that can persist throughout one's entire life [16].

Investigating oral factors that alter masticatory performance among children in the primary dentition phase is important, as mastication is a stimulus for craniofacial growth and development [17] and exerts an influence on the digestion and absorption of important nutrients for growth and health maintenance. Thus, the aim of the present study was to evaluate the influence of BMI, food consistency, and oral problems on masticatory performance among preschool children.

Material and methods

This study received approval from the Human Research Ethics Committee the Universidade Federal dos Vales se Jequitinhonha e Mucuri (Diamantina, Brazil) under protocol number 1.052.314 and conforms to STROBE guidelines.

Sample and study design

A cross-sectional study was conducted with a sample of children aged 3 to 5 years enrolled in daycare centers and preschools in the city of Diamantina, Brazil. The sample size was calculated using the formula for the comparison of two means [18] and the parameters determined during the pilot study. The pilot study was performed with 30 children allocated to three groups based on BMI (underweight, ideal weight, and overweight/obesity), as this was considered the main independent variable. Considering a standard deviation of 1.18 (referring to the median size of food particles processed for the evaluation of masticatory performance (5.70)), a 0.50 difference to be detected among groups (underweight, ideal weight, and overweight/obesity), with a 80 % statistical power and 5 % standard error, a minimum sample of 84 children was determined for each group. Nine children were added per group to compensate for possible dropouts. Thus, the total study population was 279 children. The children who participated in the pilot study were not included in the main study.

The recruitment of the sample was performed by convenience at six daycare centers and preschools in the city. Prior to initiating the investigation, the weight and height of each child were measured for the determination of the BMI, which was the basis for the allocation of the children to the different groups. After reaching 93 children per group, the statement of informed consent was sent to the parents/guardians. If a child had a BMI of a group that was already completed, he/she was not included, but could replace a child for whom the parent/guardian did not authorize participation. Children with systemic or neurological disorders, such as Down syndrome or cerebral palsy, those who made use of medications that could directly or indirectly affect muscle activity (antidepressants, muscle relaxants, or sedatives) and those who wore an orthodontic appliance were excluded from the study. Children with influenza or the common cold on the day of evaluation were evaluated at a different time, when the signs and symptoms had ceased. Only children in the primary dentition phase were included in the study. The examinations were performed between February and May 2015.

Anthropometric evaluation

To determine weight, the child was positioned barefoot with his/her school uniform, feet together, and shoulders erect on a G-Tech Glass G4FB digital scale (Accumed Produtos Médico Hospitalares Ltda, Rio de Janeiro, Brazil) calibrated to a precision of 100 g. Two hundred grams were subtracted from the weight of the child to compensate for the school uniform. Subsequently, height was determined using a portable stadiometer with a WCS vertical rod (Cardiomed, Curitiba, Brazil). BMI was calculated using the formula that divides weight (kg) by height (m) squared (BMI = kg/m^2) ([19] World Health Organization 2006). The values were plotted on a growth curve established by the WHO, considering the child's age and sex. Thus, the percentile range of each child was determined using this curve. Children with a BMI above the 96th percentile were considered obese; those between the 85th and 96th percentile were considered overweight, those between the third and 85th percentile were considered to be in the ideal range and those below the third percentile of the growth curve were considered to be underweight [19].

Clinical oral examination

The clinical oral examination was performed by a single dentist who had undergone a training and calibration exercise for all clinical conditions evaluated. The inter-examiner (in comparison to the gold standard) and intra-examiner kappa agreement coefficients were higher than 0.80 for all oral conditions evaluated. The oral examination was conducted at the daycare center or preschool. During the examination the child remained lying on a portable cot. The presence of cavitated teeth was determined using the criteria of the International Caries Detection and Assessment System (ICDAS) [20].

The number of masticatory units was based on the presence of occlusal pairs, clinically determined by the count of antagonist teeth in occlusion (adapted from studies involving adults) [21]. A child with eight molars in occlusion therefore had four masticatory units.

Malocclusion was recorded in the presence of anterior open bite, increased overjet, anterior cross-bite, or posterior cross-bite.

Breathing evaluation

The researcher kept the child seated comfortably for 5 min for observation and evaluation of the predominant breathing type. If the child spent a larger portion of the time with his/her mouth open, oral breathing was recorded. The following are the most striking characteristics of oral breathing: the tongue with the dorsum raised and the tip lowered; the tongue on the floor of the mouth or interposed anteriorly between the arches; a thick, everted lower lip; over-functioning of the mentalis muscle; flaccidity of the lips, tongue and cheeks; atypical swallowing; facial asymmetry; noisy respiration; increased height of the face; maxillary atresia; malocclusion; and a narrow, high palate [22]. All these characteristics were observed, but the confirmation of oral breathing was made by the observation of the breathing pattern at the time of the examination.

Food consistency

The mean frequency of solid foods, liquid foods, and pasty foods was evaluated using a dietary log filled out by parents/caregivers over a 3-day period. Parents/caregivers were instructed not to change the child's habitual habits on these days and the provide information on the time and foods consumed to determine data on frequency and food consistency. Parents/caregivers were also instructed to record the meals the children ate at the daycare center or preschool. If a child ingested different foods with the same consistency during a meal, only one consistency was recorded. If the child consumed foods of different consistencies, one point was awarded for each consistency. The daily frequency of the ingestion solid foods, liquid foods, and pasty foods was quantified and subsequently divided by three to obtain the mean frequency.

Evaluation of masticatory performance

Optocal [3] was the material used for the evaluation of masticatory performance, the components of which are condensation silicone (Optosil, Heraeuz Kulzer, Hanau, Germany) at a proportion 58.3 %, toothpaste (Colgate-Palmolive Ltda., São Paulo, Brazil) at a proportion 7.5 %, common dental plaster (Polidental, Cotia, Brazil) at a proportion 10.2 %, alginate powder (Jeltrate Plus, Dentisply, Milford, USA) at a proportion 12.5 %, solid petroleum jelly at a proportion 11.5 %, catalyzing paste (20.8 mg/g), and three drops of peppermint flavoring. The material was blended and inserted into molds to form cubes measuring 5.6 mm^3. The cubes were then placed into an electric oven at 60 °C for 16 h to ensure complete the polymerization. Portions of 17 cubes measuring approximately 3 cm^3 and weighing 3.2 g were separated and stored in plastic recipients until the test.

A trained examiner instructed the children to chew the 17 cubes after a training session to familiarize them with the taste and consistency of the material [15]. The examiner instructed the children that they would be told when to expel the material. After 20 masticatory cycles counted by the examiner, the material was expelled into a collector with a cap. The child's gargled with filtered water for the removal of all particles, which were also expelled into the collector. If any particle remained in the oral cavity, it was removed with clinical forceps and placed into the collector. Mastication was performed in a habitual manner [15]. The examiner who conducted the masticatory performance test was unaware of the associated variables.

The samples were filtered through filter paper, disinfected with a spray of 70 % alcohol, and dried at room temperature for 3 days. The particles were then weighed and placed into a set of nine sieves (Bertel Ltda, Caieiras, Brazil) with decreasing meshes from 5.6 to 0.60 mm. The sieves were coupled to a vibrating machine (Bertel Ltda, Caieiras, Brazil) that was kept in agitation for 20 min. The participles retained on each sieve were removed and weighed on an analytical scale with a precision of 0.001 g (AD500, Marte, São Paulo, Brazil). The distribution of the cumulative weight of the particles retained on each sieve was determined. Based on this weight, the median size of the particles for each child was calculated using the Rosin-Rammler equation [23] with the aid of the Statistical Package for the Social Sciences (SPSS 22.0).

Statistical analysis

Descriptive analysis was performed to determine the distribution of the data. The Kolmogorov-Smirnov test was used to determine the normal distribution of the data. The Kruskal-Wallis, Mann-Whitney, and chi-square tests were performed to determine the difference in distribution or mean ± standard deviation (SD) of masticatory performance and the independent variables among the underweight, ideal weight, and overweight/obesity groups. Based on the Bonferroni correction, a p value ≤ 0.017 was considered significant. The Bonferroni correction is used to address the problem of multiple comparisons based on the notion that if an examiner is testing n dependent or independent hypotheses on a set of data, one way of maintaining the error rate is to test each individual hypothesis at a statistical significance level of 1/n times what it would be if only one hypothesis was tested. Thus, if one wished the significance level for the entire set of tests to be at most a, the Bonferroni correction would involve testing each individual test at a significance level of α/n. Statistical significance simply means that a given result is unlikely to have occurred by chance, assuming that the null hypothesis is correct (i.e., no difference among groups, no effect of treatment, and no relationships among the variables) [24]. Thus, the significance value adopted ($p \leq 0.017$) is the result of 0.05/3 ($\alpha = 0.05$; three multiple comparisons = ideal weight, overweight/obese, and underweight). Simple and multiple linear regression analyses were performed to determine the associations between the independent variables (age, sex, breathing pattern, number of cavitated teeth, malocclusion, number of masticatory units, food consistency, and BMI) and masticatory performance (X50). Explanatory variables with a p value ≤0.20 were selected for the multivariate model. The stepwise method was used to determine the independent variables that remained associated with masticatory performance in the multiple linear regression model. Only explanatory variables with a p value <0.05 after the adjustment remained in the final model.

Results

A total of 257 (92.1 %) children participated through to the end. The main reason for dropouts was a lack of cooperation on the part of the child during the evaluations.

Mean age was 4.16 ± 0.77 years. Median shredded particle size (X50) was 5.57 ± 1.96 mm. Mean BMI was 16.03 ± 2.33 kg/m^2. The prevalence of cavitated teeth was 28 % ($n = 72$). There was a predominance of the daily intake of solid foods (mean, 3.99 ± 0.82), following by liquid foods (mean, 2.51 ± 0.87). The majority of the sample (54.1 %) was composed of girls. The prevalence of oral breathing was 15.6 and 57.2 % of the children had some type of malocclusion. Table 1 displays the characterization of the sample according to BMI classification groups (main independent variable).

The simple linear regression analysis showed that a greater number of cavitated teeth (both anterior and posterior, only anterior and only posterior), the daily ingestion of liquid foods and BMI were associated with a larger median particle size (X50), meaning worse masticatory performance. An older age, the number of masticatory units, and daily intake of solid foods were associated with a smaller particle size (X50), meaning better masticatory performance (Table 2).

In the final multiple regression analysis, X50 was influenced by the child's age, number of masticatory units, mean frequency of solid food and beverage intake, number of cavitated teeth (both anterior and posterior), and BMI (Table 3).

Table 1 Distribution of variables within BMI classification groups

	Ideal 86 (33.5 %)	Overweight/obese 86 (33.5 %)	Underweight 85 (33 %)	*p* value
BMI ± (SD)	15.76 (±0.06)^{a}	18.68 (±0.17)^{b}	13.62 (±0.06)^{c}	<0.001†
Age ± (SD)	4.08 (±0.08)	4.08 (±0.08)	4.33 (±0.07)	0.074†
Sex, *n* (%)				
Female	53 (61.6 %)	41 (47.7 %)	45 (52.9 %)	0.179††
Male	33 (38.4 %)	45 (52.3 %)	40 (47.1 %)	
Breathing, *n* (%)				
Nasal	76 (88.4 %)	76 (88.4 %)	65 (76.5 %)	0.047††
Oral	10 (11.6 %)	10 (11.6 %)	20 (23.5 %)	
Number of cavitated teeth ± (SD)				
Posterior and anterior	1.07	0.69 (±0.18)^{a}	1.49 (±0.28)^{b}	0.038†
Posterior	0.58 (±0.16)	0.40 (±0.10)	0.94 (±0.18)	0.037†
Anterior	0.49 (±0.16)	0.29 (±0.09)	0.55 (±0.13)	0.475†
Malocclusion, *n* (%)				
Posterior and anterior	4 (4.7 %)	4 (4.7 %)	7 (8.2 %)	0.514††
Posterior	4 (4.7 %)	7 (8.1 %)	12 (14.1 %) 48	0.090††
Anterior	48 (55.8 %)	43 (50.0 %)	(56.5 %)	0.645††
Number of masticatory units ± (SD)	3.93 (±0.04)	3.99 (±0.01)	3.89 (±0.05)	0.242†
Frequency of ingestion ± (SD)				
Pasty foods	1.32 (±0.05)	1.26 (±0.07)	1.29 (±0.07)	0.683†
Liquid foods	2.52 (±0.09)	2.52 (±0.08)	2.47 (±0.1)	0.805†
Solid foods	4.04 (±0.09)	3.91 (±0.08)	4.02 (±0.08)	0.493†
X50 ± (SD)	4.79 (±0.18)^{a}	5.67 (±0.23)^{b}	4.67 (±0.20)^{a}	<0.001†

†Kruskal Wallis test; ††chi-square test

Different superscript letters denote statistically significant differences ($P \leq 0.017$)

Table 2 Simple linear regression using association test between independent variables and X50 (dependent variable)

Dependent variable	Independent variables	B	Standard error	Beta	95 % CI (*Lower-Upper*)		*t*	*p* value*
Masticatory performance (X50)	Child's age	−0.388	0.157	−0.153	−0.698	−0.078	−2.467	0.014*
	Sex	0.161	0.246	0.042	−0.319	0.651	0.674	0.501
	Breathing pattern	0.610	0.337	0.113	−0.054	1.273	1.809	0.072
	Number of posterior and anterior cavitated teeth	0.304	0.047	0.375	0.212	0.397	6.465	<0.001*
	Number of posterior cavitated teeth	0.499	0.081	0.359	0.339	0.659	6.146	<0.001*
	Number of anterior cavitated teeth	0.496	0.093	0.318	0.314	0.678	5.358	<0.001*
	Posterior and anterior malocclusion	1.189	0.489	0.151	0.226	2.152	2.432	0.016*
	Posterior malocclusion	0.949	0.427	0.138	0.109	1.789	2.225	0.027*
	Anterior malocclusion	0.230	0.249	0.058	−0.261	0.721	0.923	0.357
	Number of masticatory units	−1.996	0.331	−0.353	−2.648	−1.344	−6.029	<0.001*
	Frequency of ingestion of pasty foods	−0.024	0.189	−0.008	−0.397	0.348	−0.129	0.897
	Frequency of ingestion of liquid foods	0.343	0.139	0.153	0.070	0.617	2.469	0.014*
	Frequency of ingestion of solid foods	−0.276	0.149	−0.115	−0.568	0.017	−1.853	0.065
	BMI	0.153	0.052	0.181	0.051	0.255	2.947	0.004*

*Simple linear regression. *CI* confidence interval

Discussion

The present study demonstrated that preschool children with a higher BMI, greater number of cavitated teeth (both anterior and posterior), and greater frequency of the ingestion of liquid foods had a worse masticatory performance. In contrast, older children, those with a greater number of masticatory units and those who consumed solid foods with greater frequency had a better masticatory performance.

Optocal was the test material used in the present investigation because it has less hardness than Optosil and is therefore indicated for children in the primary dentition phase, who could have difficulty breaking down harder material. For the evaluation of masticatory performance, the sieving method is the most commonly used when the aim is to define the median size of particles after a standardized number of chewing cycles [10]. Methods, such as optical scanning and mixing of differently colored chewing gums, have been employed for the determination of masticatory performance, but sieving has proven to be more reliable and sensitive as well as easier to use [23]. In the present investigation, children who made use of medications that depressed the central nervous system and those with cognitive impairment due to systemic or neurological disorders were excluded from the study due to the possibility of having affected muscle activity. Moreover, children who wore a fixed appliance, such as the hyrax appliance, were excluded, as muscle activity may be diminished in the first 48 h after activation [25] with a consequent reduction in masticatory performance [26].

The BMI exerted an influence on masticatory performance among the children in the present investigation, as those with a higher BMI had larger particles and

Table 3 Multiple linear regression (stepwise method) for independent variable and X50 (dependent variable)

Dependent variable	Independent variables	B	Standard error	Beta	95 % CI (*Lower-Upper*)		*t*	*p* value*
Masticatory performance (X50)	Child's age	−0.365	0.134	−0.143	−0.629	−0.100	−2.717	0.007
	Number of posterior and anterior cavitated teeth	0.264	0.047	0.325	0.172	0.356	5.650	<0.001
	Number of masticatory units	−1.383	0.322	−0.245	−2.018	−0.748	−4.291	<0.001
	Frequency of ingestion of liquid foods	0.424	0.123	0.189	0.182	0.666	3.453	0.001
	Frequency of ingestion of solid foods	−0.310	0.131	−0.130	−0.568	−0.052	−2.367	0.019
	BMI	0.186	0.045	0.220	0.097	0.274	4.138	<0.001

*Multiple linear regression; *CI* confidence interval consequently a worse masticatory performance. This finding is similar to that reported in a previous study conducted with 160 young adults when only considering the male sex [27]. However, the findings of the present investigation differ from the data reported in a study involving 15 Brazilian children in the same age group [9]. In a study involving a sample composed of 316 children and adolescents aged 6 to 16 years, a higher BMI was associated with better masticatory performance [10]. However, the sample recruited was possibly composed only of children within the ideal weight range of the BMI, based on the mean ages reported. Moreover, a previous Brazilian study demonstrated that children aged 8 to 12 years in the ideal weight range had a better masticatory performance than those with overweight/obesity [15].

Children with overweight/obesity consume a large amount of snacks that are rich in saturated fat, which are generally easy to chew [14]. Thus, the preference for foods with less consistency could lead to the under-development of chewing function, resulting in an impaired masticatory performance [28]. This is in agreement with the present findings, in which a greater consumption of solid foods led to a better masticatory performance and a greater intake of liquid foods led to a worse masticatory performance. The characteristics of foods are known to influence the masticatory process [29]. There are reports on the effect of the consistency of the diet on orofacial development, which suggests that a diet with more consistent textures stimulates bone and muscle growth and could indirectly lead to better masticatory efficiency [30].

Children with a greater number of cavitated teeth in both the anterior and posterior regions had a worse masticatory performance. This may be explained by the reduction in the area of contact for the shredding of foods, as a greater area of occlusal contact translates to better masticatory performance [5]. Moreover, the contact of the test material with the cavity could lead to stimuli of the dentinal tubules to the pulp chamber, thereby causing pain. Thus, an individual avoids using cavitated teeth during mastication [31]. Although the posterior teeth are used to shred the food, the number of cavitated teeth only in the posterior region did not remain in the final linear regression model. It is possible that children with cavitated teeth in both the anterior and posterior regions concentrate more severe carious lesions [32].

Although children with a BMI indicative of overweight/obesity had a fewer number of cavitated teeth, these two variables functioned in an independent fashion. This finding demonstrates that both an oral and systemic problem can exert an influence on masticatory performance. In this sense, common risk factors are important to the establishment of health strategies, thereby improving chewing function, which is fundamental to the growth and development of children.

Children with a greater number of masticatory units had a better masticatory performance. Those with reduced dentitions are not able to shred foods in the same manner as those with a greater number of teeth in occlusion [6]. Similar results have been found in the mixed and permanent dentitions [6, 21]. This is the first study to investigate this association in individuals in the primary dentition phase.

The mean size of the shredded particles (X50) was 5.57 (±1.96). However, it is not possible to compare this size with that reported in previous studies conducted with children in the primary dentition phase due to the different methods employed regarding the test material and evaluations [9, 11, 12]. In a study conducted with children aged 8 to 10 and 11 to 12 years and mean shredded particle size was 5.08 and 4.92, respectively [26], which demonstrates a reduction in particle size with the increase in age, as also found in a longitudinal study [33]. In the present investigation, age also exerted an influence on masticatory performance, which may be explained by the increase in the size of the masticatory muscles and the fact that chewing is a function of development that matures with experience [17].

In the present investigation, no association was found between sex and masticatory performance. The relationship may occur during puberty due to the influence of androgenic steroid hormones on bite force and a change in masticatory performance [34]. Malocclusion also exerted no influence on masticatory performance in the population studied. These findings diverge from a those of a previous Brazilian study conducted with a sample of 30 children aged 3 to 5 years [11]. According to Meng et al. [35], the temporomandibular joint in children is more flexible and prone to displacement than that in adults, which may allow the deviation of the mandible to a position in which mastication is improved. Breathing type also exerted no influence on masticatory performance, which is in agreement with data described in previous studies conducted with adults [22, 36]. According to Oliveira et al. [36], oral breathing may make mastication slower and noisier. The reduction in velocity and increase in noise do not seem to exert an influence on the fragmentation of food particles.

The present investigation has limitations such as the impossibility of establishing a causal relationship among the variables studied. Thus, it is not possible to determine whether the independent variables preceded the dependent variable. It is possible that an inverse relationship to that analyzed had occurred in the investigation of eating habits. Thus, longitudinal studies are needed.

In conclusion, a higher BMI, greater number of cavitated teeth in both the anterior and posterior regions, and a greater frequency of beverage intake exerted a negative influence on the masticatory performance of preschool children. Older children, those with a greater number of masticatory units and those who ingested solid foods with greater frequency exhibited a better masticatory performance.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Funding The study received funding from the Brazilian Coordination of Higher Education, Ministry of Education (CAPES), the Research Foundation of the State of Minas Gerais (FAPEMIG), and the National Council for Scientific and Technological Development (CNPQ), Brazil.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Prado MMS, Borges TF, Prado CJ, Gomes VL, Neves FD (2006) Função Mastigatória de Indivíduos reabilitados com Próteses totais mucoso suportadas. Pesq Bras Odontoped Clin Integr 6(3):259–266
2. Le Reverend BJ, Edelson LR, Loret C (2014) Anatomical, functional, physiological and behavioural aspects of the development of mastication in early childhood. Br J Nutr 111(3):403–414
3. Slagter AP, Bosman F, van der Bilt A (1993) Comminution of two artificial test foods by dentate and edentulous subjects. J Oral Rehabil 20(2):159–176
4. Magalhães IB, Pereira LJ, Marques LS, Gameiro GH (2010) The influence of malocclusion on masticatory performance. A systematic review. Angle Orthod 80(5):981–987
5. Aras K, Hasanreisoglu U, Shinogaya T (2009) Masticatory performance, maximum occlusal force, and occlusal contact area in patients with bilaterally missing molars and distal extension removable partial dentures. Int J Prosthodont 22(2):204–209
6. Van der Bilt A, Olthoff LW, Bosman F, Oosterhaven SP (1993) The effect of missing postcanine teeth on chewing performance in man. Arch Oral Biol 38(5):423–429
7. Toro A, Buschang PH, Throckmorton C, Roldan S (2006) Masticatory performance in children and adolescents with class I and II malocclusions. Eur J Orthod 28(2):112–119
8. Barbosa T de S, Tureli MC, Nobre-dos-Santos M, Puppin-Rontani RM, Gavião MB (2013) The relationship between oral conditions, masticatory performance and oral health-related quality of life in children. Arch Oral Biol 58(9):1070–1077
9. Gavião MBD, Raymundo VG, Rentes AM (2007) Masticatory performance and bite force in children with primary dentition. Braz Oral Res 21(2):146–152
10. Marquezin MC, Kobayashi FY, Montes AB, Gavião MB, Castelo PM (2013) Assessment of masticatory performance, bite force, orthodontic treatment need and orofacial dysfunction in children and adolescents. Arch Oral Biol 58(3):286–292
11. Gavião MBD, Raymundo VG, Sobrinho LC (2001) Masticatory efficiency in children with primary dentition. Pediatr Dent 23(6): 499–505
12. Oueis H (2009) Factors affecting masticatory performance of Japanese children. Int J Paediatr Dent 19(3):201–205
13. Nunes MS, Aiello AM, de Mello LM, da Silva AS, Nunes A (2015) Prevalence of obesity in children and adolescents in Brazil: a meta-analysis of cross-sectional studies. Curr Pediatr Rev 11(1):36–42
14. Shety PS (1999) Obesity in children in developing societies: indicator of economic progress or a prelude to a health disaster? Indian Pediatr 36(1):11–15
15. De Morais Tureli MC, de Souza BT, Gavião MB (2010) Associations of masticatory performance with body and dental variables in children. Pediatr Dent 32(4):283–288
16. Finan DS, Smith A (2005) Jaw stretch reflexes in children. Exp Brain Res 164(1):58–66
17. Ono Y, Lin YF, Iijima H, Miwa Z, Shibata M (1992) Masticatory training with chewing gum on young children. Kokubyo Gakkai Zasshi 59(2):512–517
18. Armitage P, Berry G (1987) The planning os statistical investigations. In: Statistical methods in medical research, 2ed edn. Blackwell, Oxford, pp. 179–185
19. World Health Organization (2006) Multicentre Growth Reference Study Group. WHO child Growth standards based on length/height, weight and age. Acta Paediatr Suppl 450:76–85
20. Pitts N (2004) ICDAS—an international system for caries detection and assessment being developed to facilitate caries epidemiology, research and appropriate clinical management. Community Dent Health 21(3):193–198
21. Ueno M, Yanagisawa T, Shinada K, Ohara S, Kawaguchi Y (2008) Masticatory ability and functional tooth units in Japanese adults. J Oral Rehabil 35(5):337–344
22. Rodrigues HOSN, Faria SR, Paula FSG, Motta AR (2005) Ocorrência de respiração oral e alterações miofuncionais orofaciais em sujeitos em tratamento ortodôntico. Rev Cefac 7(3):356–362
23. Van der Bilt A, van der Glas HW, Mowlana F, Heath MR (1993) A comparison between sieving and optical scanning for the determination of particle size distributions obtained by mastication in man. Arch Oral Biol 38(2):159–162
24. Riffenburgh RH (2006) Statistics in medicine, 2nd edn. Elsevier, San Diego
25. Goldreich H, Gazit E, Lieberman MA, Rugh JD (1994) The effect of pain from orthodontic arch wire adjustment on masseter muscle electromyographic activity. Am J Orthod Dentofac Orthop 106(4): 365–370
26. Magalhães IB, Pereira LJ, Andrade AS, Gouvea DB, Gameiro GH (2014) The influence of fixed orthodontic appliances on masticatory and swallowing threshold performances. J Oral Rehabil 41(12): 897–903
27. Isabel CA, Moyses MR, van der Bilt A, Gameiro GH, Ribeiro JC, Pereira LJ (2015) The relationship between masticatory and swallowing behaviors and body weight. Physiol Behav 151:314–319
28. Yamanaka R, Akther R, Furuta M, Koyama R, Tomofuji T, Ekuni D, et al. (2009) Relation of dietary preference to bite force and occlusal contact area in Japanese children. J Oral Rehabil 36(8): 584–591
29. Van Der Bilt A (2011) Assessment of mastication with implications for oral rehabilitation: a review. J Oral Rehabil 38(10):754–780
30. Little BB, Buschang PH, Pena Reyes ME, Tan SK, Malina RM (2006) Craniofacial dimensions in children in rural Oaxaca, Southern Mexico: secular change, 1968-2000. Am J Phys Anthropol 131(1):127–136

31. Tate GS, Throckmorton GS, Ellis E, Sinn DP (1994) Masticatory performance, muscle activity, and occlusal force in preorthognathic surgery patients. J Oral Maxillofac Surg 52(5):476–481
32. Ramos-Jorge J, Alencar BM, Pordeus IA, Soares ME, Marques LS, Ramos-Jorge ML, Paiva SM (2015) Impact of dental caries on quality of life among preschool children: emphasis on the type of tooth and stages of progression. Eur J Oral Sci 123(2):88–95
33. Barrera LM, Buschang PH, Throckmorton GS, Roldan SI (2011) Mixed longitudinal evaluation of masticatory performance in children 6 to 17 years of age. Am J Orthod Dentofac Orthop 139(5):427–434
34. Shiau YY, Wang JS (1993) The effects of dental condition on hand strength and maximum bite force. J Cranio Praties 11(1):48–54
35. Meng F, Liu Y, Hu K, Zhao Y, Kong L, Zhou S (2008) A comparative study of the skeletal morphology of the temporo-mandibular joint of children and adults. J Postgrad Med 54(3):191–194
36. de Oliveira RLB, Noronha WP, Bonjardim LR (2012) Avaliação da performance mastigatória em indivíduos respiradores nasais e orais. Rev Cefac 14(1):114–121