Masticatory performance and bite force in children with primary dentition

Performance mastigatória e força de mordida em crianças na dentição decídua

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Abstract: The aim of this study was to evaluate the relationship between masticatory performance and maximum bite force in the primary dentition. The sample comprised 15 children of both genders, aged 3 to 5.5 years, with good systemic and oral health, presence of all primary teeth without large caries, no structural anomalies, without severe malocclusion, and no history of orthodontic treatment. They chewed one standardized silicone tablet for 20 strokes and the median areas of the chewed particles were measured by an optical digital system. Enhanced performance was measured by a decrease in the chewed particle areas and an increase in the amount of chewed particles. The bite force was determined using a transmitter pressurized tube connected to an analog/digital electronic circuit. Weight, height and body mass index (kg/m^2) were determined. The data were analyzed by descriptive statistics and Pearson or Spearman's correlations, after assessment of the normality of the distribution by Shapiro-Wilks' *W*-test. There was no correlation between bite force and particle area and amount ($p > 0.05$), neither were the body variables correlated with the masticatory variables ($p > 0.05$). It was concluded that the bite force was not a primary determinant of masticatory performance, and both variables were not dependent on body variables in the studied sample.
Descriptors: Mastication; Bite force; Dentition, deciduous.

Resumo: O objetivo deste estudo foi avaliar a correlação entre performance mastigatória e força de mordida máxima na dentição decídua. A amostra consistiu de 15 crianças de 3 a 5,5 anos de idade, de ambos os gêneros, apresentando boa saúde bucal e sistêmica, com a presença de todos os dentes decíduos, sem cáries extensas, sem anomalias estruturais, sem maloclusão severa e ausência de tratamento ortodôntico. Um tablete de silicone foi mastigado durante 20 ciclos e as áreas medianas das partículas foram mensuradas por um sistema óptico digital. A performance mastigatória foi considerada melhor quanto menor o tamanho das partículas mastigadas e quanto maior o número das mesmas. Para a força de mordida utilizou-se um tubo transmissor pressurizado, conectado a circuito eletrônico analógico/digital. O peso, a altura e o índice de massa corporal (kg/m^2) foram determinados. Os dados foram analisados pela estatística descritiva e correlacionados pelo coeficiente de Pearson ou Spearman, após a avaliação da normalidade da distribuição pelo teste de Shapiro-Wilks. Não houve correlação significativa entre a força de mordida e as áreas e o número das partículas ($p > 0,05$), assim como as variáveis corporais não se correlacionaram com as variáveis mastigatórias ($p > 0,05$). Concluiu-se que a força de mordida não foi o principal determinante da performance mastigatória na amostra avaliada, e ambas não foram dependentes das variáveis corporais.
Descritores: Mastigação; Força de mordida; Dentição decídua.

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Introduction

Mastication is a developmental function and its maturation occurs from learning experiences. If it is adequate, it gives stimulus and proper function for the normal development of the maxilla and mandible.[20] As mastication results in reducing the size of food particles in preparation for swallowing and digestion, its performance can be measured by determining the individual capacity to comminute a test food.

Artificial foods may be preferred to natural foods for measuring masticatory performance because the physical properties, shape and size of the particles are more reproducible.[2,11] Fractional sieving has been widely used to determine the degree of breakdown of the chewed food.[2,11,21] Nevertheless, the accuracy and specificity of an optical system, in which the projected dimensions of the comminuted food particles can be measured, is accompanied by an increase in speed over the conventional method.[17]

Several factors influence masticatory performance, including severity of the malocclusion,[3] occlusal contact area and body size,[11,21] number of functional tooth units and bite force.[5,9] The areas of contact between occluding teeth determine the area available for shearing food during chewing cycles.[11] Deteriorated dentition and malocclusions can decrease performance.[5,26]

The bite force is one of the components of the chewing function. It increases with age from childhood,[1] stays fairly constant from 20 to 40 years of age and then declines.[6] Hatch *et al.*[9] (2001), in a large sample of 283 men and 348 women aged from 37 to 80 years, found the mean bilateral bite force in the molar region to be 583.49 ± 281.11 N. In ages from 7 to 20 years, the mean values of unilateral bite force were 309.50 ± 193.75 N for boys and 219 ± 144.21 N for girls.[24]

In children aged 3-5 years old, Kamegai *et al.*[12] (2005) observed that the mean bite force was 186.2 N in boys and 203.4 N in girls, whereas Maeda *et al.*[14] (1989) found values of 212.16 N in this age range. For Rentes *et al.*[23] (2002), the mean value was 213.17 N in children from 3 to 5.5 years old with normal occlusion.

Facial structure, general muscular force and gender differences are only a few factors that may influence bite force values.[13] Other factors, such as state of dentition, instrumentation design and transducer position related to dental arch,[15,25] malocclusions, signs and symptoms of temporomandibular disorders; size, composition and mechanical advantage of jaw-closing muscles, may influence the values found for bite force.[1,15,25] Thus, the subjects' sensory feedback may limit willingness to exert the maximum effort.[6]

The primary occlusion directly influences the development of the permanent dentition[16], and conditions that are known to interfere with growth and development should be considered.[18] Therefore, the purpose of this study was to evaluate masticatory function in children with primary dentition, checking the relationship between masticatory performance and maximal bite force.

Material and Methods

The study comprised children of both genders aged 3 to 5.5 years. The procedures, possible discomforts or risks, as well as the possible benefits, were fully explained to the children and their parents/guardians, and their informed consent was obtained. The Ethical Committee of our Dental School approved the research. The inclusion criteria were the presence of all the primary teeth, without variations that could compromise their dimensions, such as large caries and structural anomalies, normality of the oral tissues and no history of orthodontic treatment. The exclusion criteria were systemic disturbances in general, ingestion of medicines that could interfere directly or indirectly with muscular activity, uncooperative behavior, tooth anomalies of structure, number or form, large caries and/or restorations, bruxism, indicated clinically by the presence of bruxofacets, and severe malocclusion. About thirty children were selected, but only 15 cooperated and performed the two tests properly, despite the training before the experiments. The sample size was determined taking into account the correlation coefficients found in the literature[5,14,15,19] for a power test of 0.8, being 15 subjects a sufficient number.

Body weight and height were determined by an anthropometric balance and body mass index (BMI = weight/heigth^2) was calculated.

Masticatory performance and bite force measurements

The masticatory performance and bite force measurement procedures had been previously described,[7,23] and they were applied by two trained dental students, with the supervision of a pediatric dentist. Briefly, the median particle areas (mm^2) and the number of chewed particles were used as representative values of masticatory performance. A decrease in the measurements and an increase in the number of the particles were considered as representative of enhanced performance. The test material was a round tablet (5 mm in thickness and 10 mm in diameter, 1.6 ± 0.005 g) of condensed silicone (Optosil, Bayer, Leverkusen, Germany). Optosil is an appropriate material for the optical method, validated by Mowlana *et al.*[17] (1994). Each child chewed one tablet for a total of 20 bilateral strokes, which were considered adequate as they did not lead to chewing stress, as assessed during the training before the actual test. After that, they spat the particles into a plastic cup, rinsed their mouth with water and spat the remaining mouth contents until all particles were removed. It was verified that no particle remained. After the particles dried, they were weighed in order to assess the lost material. The test was repeated when there was any loss of material greater than 6%. The particles in each cup were transferred to a tray with a dark background and disconnectedly distributed, allowing correct digital analysis of all pieces. Each tray was photographed using a standardized particle-camera distance. Digital images of the particles were obtained on a table scanner (HP ScanJet 4c/T scanner, Hewlett-Packard, Palo Alto, CA, USA) and analyzed by Image Lab software (Softium Informática Ltda.-ME, Fortaleza, CE, Brazil).

The bite force measurement methodology was based on that of Braun *et al.*[1] (1996), modified by Rentes *et al.*[23] (2002) for applicability in pre-school children. The system consisted of a pressurized rubber tube, with a diameter of 7 mm, which is adequate for the primary dentition, connected to a sensor element (MPX 5700 Motorola SPS, Austin, Texas, USA), with a converse analog/digital electronic circuit. The system was connected to the computer and software for reading the pressure was developed. During its use, the tube was elastically deformed, conforming to the occlusal anatomy of the individual maxillary and mandibular teeth, thereby providing a more uniform force distribution[1]. This deformation is important because it gives the subjects a degree of psychological security unlike the typical metal biting elements.

The subject bit the tube, placed between the posterior maxillary and mandibular teeth, with maximum force, 3 times successively for 5 seconds, with a 10-second interval. The highest value was considered, i.e., the maximal force generated, obtained in Psi and converted to Newton, taking into account the area of the tube, since force (F) is equal to pressure (p) times area (a) (equation 1).

$$F = p \times a \quad (1)$$

The average bite force values of all the three measurements were in line with the maximum values. The method error was applied to check the reproducibility on repeated measurements, at two separate occasions of 10 randomly selected children not included in the study, using Dahlberg's formula:

$$S_e = \sqrt{\frac{\Sigma(m1 - m2)^2}{2n}}$$

where:

m: measurement;

n: selected participants;

S_e: errors of measurements.

They underwent the measurements at intervals of at least 21 days, using the same method as with the experimental subjects. There were no differences between the sets of two measurements. The error for the bite force was 5.04 N. For masticatory performance, represented by the particles sizes, it was 0.6 mm^2.

Despite the fact that the children had been motivated for the procedures, which were non invasive, some of them refused to chew the silicone tablet due

Table 1 - Individual data and descriptive statistics of particle area, bite force, body variables and age.

Child	Bite Force (N)	Area (mm^2)	Particles (number)	Weight (kg)	Height (m)	BMI (kg/m^2)	Age (years)
1	161.10	2.86	22	17.10	1.10	14.13	3.7
2	182.43	0.77	39	16.50	1.05	14.97	3.3
3	182.47	0.47	48	18.70	1.09	15.74	4.2
4	203.29	2.62	18	21.00	1.10	17.36	4.6
5	224.38	1.17	39	21.50	1.12	17.14	5.3
6	224.38	0.54	56	14.50	1.01	14.21	3.2
7	224.38	1.09	33	15.00	0.94	16.98	3.1
8	231.57	1.51	47	20.20	1.16	15.01	4.7
9	238.29	1.89	19	19.00	1.05	17.23	5.0
10	238.52	3.95	12	24.00	1.10	19.83	5.2
11	245.24	0.30	32	26.00	1.10	21.49	5.4
12	273.29	2.07	24	18.50	1.12	14.75	4.7
13	280.48	0.78	12	21.70	1.15	16.41	4.8
14	287.43	0.90	29	20.00	1.14	15.39	5.4
15	329.62	4.31	11	17.00	1.10	14.05	3.9
Medians	231.57	1.17	29	19.38	1.09	15.74	4.7
Range	168.52	4.01	45	11.5	0.22	7.44	2.3
Means	235.12	1.68	29.40	3.19	0.06	16.31	4.43
SD	± 44.48	± 1.26	± 14.23	± 3.19	± 0.06	± 2.13	± 0.82
SEM	± 11.49	± 0.32	± 3.67	± 0.82	± 0.02	± 0.55	± 0.21

SD: Standard deviation. SEM: standard error of the mean. BMI: Body mass index.

to its tasteless characteristic or did not allow placing of the tube on their posterior teeth, biting improperly. Therefore, they were excluded.

Statistical analysis

The normality of the data distributions was assessed by Shapiro-Wilks' *W*-test. The chewing and body variables were normally distributed, except for height. Data were analyzed by descriptive statistics and Pearson and Spearman's coefficients. The significant level considered was $p < 0.05$. The Sigma Stat 3.0 statistical package (SPSS Inc., Chicago, IL, USA) was used.

Table 2 - Correlation coefficients of masticatory performance and body variables.

	Bite force	Area	Particles	Weight	Height	BMI
Bite force	-	**0.370**	**0.102**	**0.543**	**0.072**	**0.979**
Area	0.250	-	**0.005**	**0.935**	**0.486**	**0.794**
Particles	–0.439	–0.683	-	**0.243**	**0.391**	**0.416**
Weight	0.171	0.023	–0.321	-	**0.017**	-
Height	*0.477*	*0.195*	*–0.239*	*0.603*	-	-
BMI	–0.007	–0.074	–0.227	-	-	-

In regular text: Pearson's coefficients. In italic text: Spearman's coefficients. In bold text: p-values. BMI: Body mass index.

Results

The individual data are listed in Table 1. The correlation coefficients and respective p-values are presented in Table 2. There were no correlations between particle areas, number, bite force, and body variables ($p > 0.05$).

Discussion

The methods used in this study for measuring masticatory performance and bite force in pre-school children were previously developed and used,[7,23] having proved to be adequate for field work. Comparisons with other studies are tricky, since values of masticatory performance may be confounded by the use of different methodologies. Nevertheless, the results of bite force were similar to those of other studies in pre-school children,[14,15] despite the different devices used.

Applicability of these methods depends on children collaboration. Young children have more difficulty following instructions and may be less likely to perform the tasks properly. Thus, they received detailed experimental instructions and motivation, chewed the silicone tablets and tested the biting equipment several times before the actual recordings were made in order to build confidence in the test procedures. Although some children were excluded from the study because they did not collaborate, we perceived that young children are able to perform the tests well.

Masticatory performance and bite force were independent of each other, since there was no correlation between particle areas and bite force values (Tables 1 and 2). In children, low variability should occur in bite force,[11] but chewing maturation is a learned behavior,[20] thus allowing an improvement in performance. Moreover, chewing in small children depends on the daily performance and on the neuronal and psycho-social maturation as well as on the developmental status. Therefore, the muscle efficiency and force generated during mastication could not be considered the primary determinants of masticatory performance in the studied sample, agreeing with others.[19,26]

The lack of correlation between masticatory variables in this study could also be attributed to the dietary habits of today. The increasing softness of food is an environmental factor that might exert a strong influence on occlusal force.[15] The occlusal force of children who mainly ate a soft diet was significantly lower than that of those who ate a more fibrous diet.[14] Hence, it is important to evaluate the child's diet in relation not only to the nutritional and cariogenicity aspects, but also in relation to its consistency, which may determine if he/she will acquire a good chewing pattern and strength of the masticatory muscles, thus influencing the development of the masticatory system.

On the other hand, the number of posterior functional teeth has been considered one of the best predictors of masticatory performance[9,26] because the contacts between occluding teeth determine the area available for shearing and grinding food during the chewing cycle.[5,9,11] This could explain the present findings, as children had no missing teeth. Another factor that influences masticatory performance is the amount of lateral excursion during mastication. Occlusal wear may eliminate interferences, permitting a greater range of lateral movements.[8,10] There is a high prevalence of occlusal tooth wear in the primary dentition as a physiological condition, which determines greater contact areas, improving the masticatory function.[8-10,21]

Median particle areas and bite force were not correlated with body variables. The expected influences of body size upon masticatory variables must occur later due to the increase in muscle mass.[3,24] These findings are in agreement with those of other studies that observed no significant correlations between bite force and body variables in children,[13,23] as well as between masticatory performance and body variables in primary dentition.[7] The bite force evidently may depend on more complex factors than body size, such as the cross-sectional area of the masticatory muscles and jaw biomechanics.[22] Another factor is dental occlusion, although there are contradictory results in the literature. No statistical difference were observed in maximal bite force with different kinds of occlusion in the primary dentition,[12,23] whereas the occlusal conditions in this phase had an influence on masticatory performance.[7] In older children and adolescents, bite force was not correlated with the Angle classification,[21,24,25,27] but correlated with maxillary protrusion, anterior crossbite, crowding and open bite,[12] suggesting that the quality of occlusion determines masticatory performance to a greater degree than the level of force that the subjects are willing to generate. The influence of any discrepancy in bite force can become apparent during eruption and establishment of the permanent dentition. Studies taking into account occlusion in the primary dentition in a larger sample are necessary to assess its influence on the relationship between masticatory performance and bite force.

Chewing places a functional demand on the stomatognathic system throughout life. A panoramic view of the changes that occur during growth may give insight into naturally occurring relationships between form and function.[8] The three years prior to initiation of the mixed dentition are crucial, in that normal changes of growth and functional adaptability occur. In young children, peripheral sensorimotor pathways that underlie the jaw stretch reflex are maturing as the child continues to acquire oral motor skills.[4] Since the primary occlusion undergoes continuous change and it is adapting to growth and developmental functional patterns, its functional determinants can and must be established to explain and assure appropriate growth and development of the stomatognathic system and to allow a better understanding of the functional aspects of the masticatory system development.

Conclusions

Masticatory performance was independent of muscular force, and body variables had no influence upon masticatory variables in the studied sample.

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