Masticatory efficiency in children with primary dentition

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Abstract

Purpose: *The aim of this study was to evaluate masticatory efficiency in children with normal primary occlusion and malocclusion and to correlate efficiency with body variables.*

Methods: *Thirty children were divided into three groups: Group I with normal occlusion (n=10), Group II with posterior crossbite (n=10) and Group III with anterior open bite (n=10). They chewed standardized silicone tablets for 20 strokes and the optical scanning system was used to calculate the particle size (area and perimeter). Results were compared among the groups. Body weight and height were correlated with masticatory efficiency.*

Results: *Group I fragmented the tablets into a greater number of particles with smaller sizes than Groups II and III, and the differences were statistically significant ($p<0.05$). There was no difference between the children with crossbite and children with open bite. Correlation coefficients between body variables and masticatory efficiency were weak ($p>0.05$).*

Conclusions:. *Occlusion is a factor of influence on masticatory process. (Pediatr Dent 23:499-505, 2001)*

Mastication is considered the first step in the digestive process and is under the control of the central pattern generator located in the brain stem. The mechanical breakage of foods makes enzymatic processing easier in the digestive system, since this mechanism is influenced by the way that foods are chewed.[1] Mastication is a developmental function and its maturation occurs from learning experiences.[2] If adequate, it provides stimulus and proper function to the normal development of the maxilla and mandible. The general coordinative organization of chewing is well established by 12 months of age but continues to be refined during early development. In more general observations of motor skill acquisition, development of chewing appears to be characterized by decreased variability and increased motor efficiency.[3]

As mastication results in size reduction of food particles in preparation for swallowing and digestion,[4] its efficiency can be measured by the capacity of the individual to comminute a natural or artificial test food. The application of human masticatory performance as an outcome measurement depends on the improvement of internal validation through standardization (ie controlling the sources of potential variation). Bolus size and chewing rate remain to be standardized, particularly for artificial test foods. For natural test foods, the relationship between bolus size and performance remains controversial.[5] Artificial test foods may be preferred to natural test foods for measurements of masticatory performance and efficiency, since the physical properties, shape and size of the particles are more reproducible.[6,7] Fractional sieving has been used widely to determine the degree of breakdown of chewed food.[6-10]

An alternative to sieving was introduced—the optical system, in which the projected dimensions of the comminuted food particles were measured using a video camera. The optical system has a distinct advantage over the techniques employed in measuring chewed particles with its unique ability to count and measure individual particles in a given sample of chewed test food whether artificial or natural. The system accuracy and specificity are accompanied by an increase in speed over the conventional method. Scan data are directly available for computer analysis minimizing handling of data, whereas with sieving the obtained weights must be typed before computer analysis is possible. The optical method is also useful when interest is restricted to relatively large particles, such as after the first few strokes on hard foods. The optical method requires little skill to use the equipment and is therefore simple to use and much faster than sieving. It also provides accurate enumeration over a wide range of sizes as well as providing detailed two-dimensional data from which the fracture patterns can be inferred.[11]

Several factors potentially influence masticatory efficiency, including severity of malocclusion,[12] occlusal contact area and body size,[13] number of functional tooth units and bite force.[14,15] The surface area of the teeth, particularly the areas of contact between occluding teeth, determines the area available for shearing food during each chewing cycle.[13,16] Nevertheless, Wilding[17] concluded that differences in the movement of the jaw and in the bite force might have a greater influence on chewing efficiency than the occlusal contact areas. Someone with carious, painful teeth will unconsciously avoid those teeth during mastication, reducing their masticatory efficiency. Patients with dental and skeletal malocclusions would be expected to have poor masticatory performance due to fewer occlusal contacts, as demonstrated by Tate et al[18] in preorthognathic surgery patients who presented poorer masticatory performance than controls and no correlations with estimated forces and muscle efficiency. This suggests that occlusal relationships and mechanical advantages contribute to a person's ability to chew.

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Table 1. Morphological Occlusion of Groups

Morphological characteristics	Group I (n=10) (Normal occlusion)	Group II (n=10) (Posterior crossbite)	Group III (n=10) (Anterior open bite)
Terminal relation of second molars	Flush terminal plan/ mesial step	Flush terminal plan/ mesial step/distal step	Flush terminal plan/ mesial step/distal step
Incisal relation	Overbite 0.5-2.5mm Overjet 0-2 mm	Overbite 0.5-2.5 mm Overjet 0-2 mm	Overbite >0 Overjet >0
Canine relation	Class I	Class I, II, III	Class I, II, III
Canine buccolingual relation	Normal	Normal/cross	Normal
Molar buccolingual relation	Normal	Cross	Normal

Table 2. Descriptive Statistics for Particle Sizes – Area (cm^2) and Perimeter (cm)

	Area			Perimeter		
	Mean	SD	SEM	Mean	SD	SEM
Group I	0.17 a	0.06	0.02	1.62 a	0.35	0.09
Group II	0.36 b	0.10	0.03	2.41 b	0.53	0.13
Group III	0.32 b	0.03	0.03	2.23 b	0.15	0.15

Means followed by the same small letter in the column indicate no statistical difference at the 95% confidence level (Tukey test, p<0.05)

Table 3. Descriptive Statistics for Measures of Body Variables – Weight (kg) and Height (m)

	Weight			Height		
	Mean	SD	SEM	Mean	SD	SEM
Group I	17.55	2.23	0.56	1.09	0.05	0.01
Group II	21.15	2.02	0.50	1.12	0.04	0.01
Group III	17.92	3.32	0.83	1.13	0.24	0.06

By the age of 2-1/2 years, the primary dentition has fully erupted, characterized by the flatness of the occlusal plane, interdental spacing and small overlap of the incisors. Flush terminal plane is the most prevalent, following by mesial step and distal step occlusion. Very little change takes place until eruption of the first permanent tooth, but malocclusions can occur in the periods prior to occlusal maturity and different types can be diagnosed. Posterior crossbite is one of the most frequent orthodontic problems and it is estimated that about 8% to 26% of the children in primary dentition present this type of malocclusion.[19,20] Its origin may be either skeletal or dental, or a combination of the two, and can lead to mandibular displacement accompanied by lower midline deviation.[21] Vertical malocclusion, such anterior open bite, develops as a result of the interaction of many different etiologic factors including finger or pacifier sucking, lip and tongue habits, airway obstruction and true skeletal growth abnormalities.[22,23]

Primary occlusion directly influences permanent dentition development in both functional and morphological aspects.[24,25] The recognition of conditions that are known to interfere with growth and development should be considered.[26] Although there are many reports concerning morphological aspects of occlusion during primary dentition,[27-30] its functional aspects are not sufficiently clear yet. There are few studies about masticatory efficiency in early ages.[31,32] However no study has presented any information on the possible influence of normal occlusion and malocclusion on masticatory efficiency in the primary dentition. Considering these facts, as mastication is a function directly related with development of the maxilla and mandible and masticatory efficiency is dependent on the occlusion,[2,12,18,33] this study aimed to evaluate masticatory efficiency in children with primary dentition, presenting normal occlusion, posterior crossbite and anterior open bite, by monitoring the chewing of artificial test food, digitally analysing the particles obtained, and correlating these with body variables (weight and height).

Methods

Sample

The study comprised 30 children of both genders aged 3 to 5.5 years who were to start dental treatment at the Dental School of Piracicaba, State University of Campinas. Written and verbal consent were obtained from each child's parents/guardians after they had been informed about the procedures, possible discomforts or risks as well as the possible benefits. The research was approved by the Ethics Committee of the Dental School. The children were selected after the parents/guardians answered a screening questionnaire, verifying the absence of systemic disturbances, which could compromise the masticatory system. The criteria for inclusion was the presence of the all primary teeth, without form, structure or number anomalies, without alterations that could compromise their cervico-occlusal and mesio-distal dimensions, and the normality of the oral tissues.

A standard clinical examination, which included a morphological and functional evaluation of the masticatory system, was performed. The morphological examination of occlusion was carried out in accordance with the criteria of Foster and Hamilton[27] and Saadia[28] verifying the terminal relation of second molars, buccolingual relation of the molars, canines and incisors, antero-posterior relation of the canines, overjet, and overbite. The functional occlusal examination included the evaluation of intercuspal tooth position, extent of lateral movements, maximum opening and presence of asymmetry.

After all parameters had been verified, the sample was divided into three groups, with 10 children in each one, according to the type of the occlusion, ie normal occlusion - group I, posterior cross bite - Group II, and anterior open bite - Group III (Table 1). The children showed no signs or symptoms of temporomandibular joint dysfunction and the functional occlusal examination was considered normal, except for three children in group II, who presented mandibular displacement accompanied by lower midline deviation, which represent characteristics of the posterior crossbite. They had no history of previous orthodontic treatment. Body weight and height were determined and correlated with the masticatory efficiency.

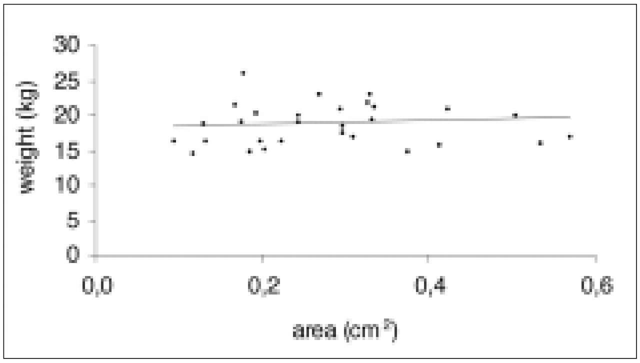

Fig 1. Correlation of area and weight (y=2,7074x+18,101, R^2=0,0134)

Artificial Test Food

The material utilized was a condensation silicone impression (Optosil, Bayer),[6,7] prepared as follows: Tablets, approximately 5 mm thick and 20 mm in diameter[6] and 5mm thick and 10 mm in diameter, were tested before the actual test. Five mm x 10 mm was found to be of an appropriate size for the portions, as well its shape, offering comfortable conditions for performance of the test, considering the children's age. The Optosil material was placed in a split mould and pressurized into the perforations between two thin glass plates protected with teflon foil, by hydraulic pressure using a press set at 50 kP/cm.[2] Each portion was weighed and, if weight variation was observed, the tablet was cut down by hand to a weight of 1.587±0.005 g. The completed test portion then was rounded to a tablet formation. This meant that from the beginning of mastication the test portion would be broken in a uniform way.

Chewing test

Children were instructed to chew one tablet for a total of 20 chews and were trained before the experiment in relation to masticatory movements and mouth rinsing so that they would chew correctly, not swallow and be familiarized with the taste of the test material. During the chewing test they performed 20 bilateral strokes, controlled by the examiner. After the mastication the child spat out the sample into a plastic cup and the mouth was rinsed with water. The child then spat out the remaining mouth contents until all particles were removed. After that, the mouth was verified to check that no test material particles remained. If any particle remained it was removed. After one hour, by which time the viscosity of the saliva had been reduced and the pieces had fallen to the bottom of the plastic cup,[6] the water and the spittle excess were drained and the residual fluid was left to evaporate. When the fragmented particles were dried, they were weighed to verify that no material was lost. The test was repeated when loss was greater than 6%, so the particles distribution should not be affected.[34]

Digital image analysis

The particles of each recipient were transferred to a tray with a dark background where they were distributed so as not to superpose, allowing correct digital analysis of all pieces. Each tray, with the particles of each child, was photographed using a standardized-distance particle camera sustained by a support. Flexible optical filament fountains provided the proper incident light. Digital images of the particles were obtained by digitizing on a table scanner, model HP-Scanjet 4C/T, with a resolution of 150 dpi and with 16 million colors. Images were analyzed by Image Lab software (Softium Informatica Ltda-ME). Using the reference points of the photos, the system was calibrated to convert the image-digitized dimensions (pixel) into real dimensions (cm). Images were then filtered to remove the noise. The fragments were selected in the image with the color difference as the discriminate parameter. The area and perimeter of each fragment in several images were quantified and sent to Excel, where their means were obtained to provide data for the application of statistical analysis.

Statistical analysis

Data were analyzed by conventional statistical methods, ie, arithmetic mean, standard deviation and standard error of the mean. Analyses of variance evaluated difference among the three groups and Tukey's *post-hoc* test was used to evaluate differences among the means. Pearson correlation coefficient (r) was used to test the significance of correlations between the particle sizes and the body variables. Multiple regression analysis was used to investigate the importance of body variables in determination of the particle sizes.

Results

The means of area and perimeter of the particles are demonstrated in Table 2 and the means of weights and heights are shown in Table 3. The means particle sizes of the group with normal occlusion were statistically smaller than those of the groups with malocclusion ($p<0.05$). Group I fragmented the tablet to a greater number of particles with smaller sizes. However, there was no difference between the children with crossbite and children with open bite.

Multiple regression analysis showed that particle sizes were not correlated with the body variables: area and weight (r = 0.04)(Fig 1), area and height (r = 0.17) (Fig 2), perimeter and weight (r = -0.06) (Fig 3) and perimeter and height (r = 0.03) (Fig 4). These correlation coefficients were not statistically significant ($p>0.05$), demonstrating weak correlation between the variables.

Discussion

The test material used is of great importance for evaluating masticatory efficiency. The physical and chemical characteristics of the food itself directly influence jaw and muscle performance.[9,35,36] Artificial test foods may be preferred to natural foods for measurements of masticatory performance and efficiency, as the physical properties, shape and size of their particles are more reproducible.[6,7] Natural foods are not constant in size, shape, hardness, etc. and comparison of jaw performance on such foods is therefore not appropriate. Artificial test foods provide constant physical characteristics, yet

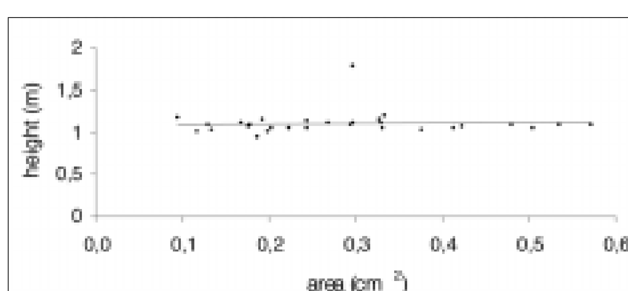

Fig 2. Correlation of area and height (y=0,0429x+1,0985, R^2=0,0015)

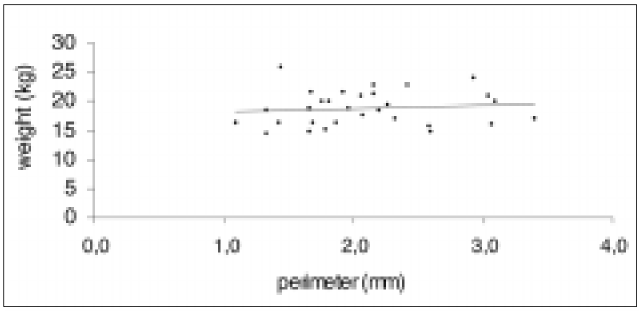

Fig 3. Correlation of perimeter and weight ($y=0{,}4925x+17{,}845$, $R^2=0{,}0094$)

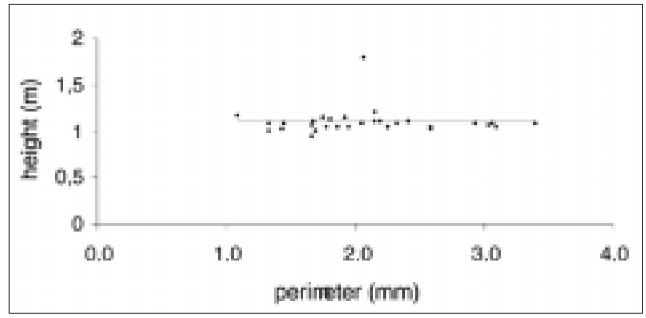

Fig 4. Correlation of perimeter and height. ($y=-0{,}0005x+1{,}1113$, $R^2=4E-06$)

their non-edible nature unavoidably affects the natural pattern of jaw movement.[37] Optosil, a condensation silicone impression material, has been used extensively for studies of masticatory function, predominantly in dentate subjects. Since the demonstration of its suitability,[6] Optosil has become the test food of choice.[9,12,34,38] In this study we chose Optosil as the test food due to the considerations mentioned above and because it was a suitable material for our children, well accepted during the training before the actual test. In addition, it was possible to recover almost all material chewed (94-98%). The number of 20 cycles was standardized since it was an adequate number, as perceived during the trials, and did not lead to chewing stress.

When the results are compared among the three groups, it can be observed that the mean of particle size in Group I was smaller than those of Groups II and III. Thus, children with normal occlusion were able to fragment the test material into smaller particles of a larger quantity than the other groups. These results were statistically significant, meaning that the occlusal conditions may be an influencing factor in masticatory performance, an occurrence also reported by Henrikson et al[33] in girls aged 11-15 years with normal occlusion, who presented better masticatory efficiency and ability than subjects with Class II malocclusion. According to these authors, 30 percent of the variation in masticatory efficiency could be explained by few occlusal contacts and large overjet, and therefore these variables could predict a reduced masticatory efficiency. The number of occlusal contacts in each child may be a contributing factor to a child's ability to efficiently chew his/her food.[17]

The surface area of the teeth, particularly the areas of contact between occluding teeth, determines the area available for shearing food during each chewing cycle. Individuals who had the largest wear facets on the occlusal surface also had the highest amount of occlusal contact.[13] Occlusal contact information was not quantified in the current study, but it is reasonable to assume that the children with malocclusion had fewer occlusal contacts than the controls.

Occlusal wear may also eliminate interferences, permitting a greater range of lateral excursion.[39] There is a high prevalence of incisal and occlusal tooth wear in primary dentition, as verified by Hugoson et al[40] and Nyström et al,[41] whose results suggested that tooth wear progressed faster in the primary dentition than in the permanent dentition. Thus, tooth wear may be considered to be a physiological occlusal condition, mainly in the normal occlusion in the primary dentition, increasing the occlusal contact areas and contributing to normal maxillo-mandibular development.

Nevertheless, Harper et al,[42] verifying that the number of occlusal contacts did not differ in children with Juvenile Rheumatoid Arthritis (JRA) and controls, concluded that occlusal contacts were not a factor in the chewing performance. JRA children compromised their masticatory function as a pain avoidance mechanism, showing the influence of systemic disorders in chewing performance. Our sample was composed of healthy children with no systemic disturbances, which could compromise their masticatory system and infer other influencing factors on the obtained findings.

The chewing pattern of young children at the level of occlusion is well established with the completion of the primary dentition.[39,43] The skeletal structure and neuromuscular system develop as a child's dentition changes from primary to mixed and finally to permanent dentition. This development may include an adaptation of the functional system to the new dental conditions. Furthermore, the maturation of the nervous system and the process of learning during childhood may influence posterior oral motor behavior, so normal development of primary and mixed dentition is indispensable in establishing a healthy chewing movement in the permanent dentition.[43-45]

The knowledge of mandibular excursions provides a better understanding of normal mandibular movement and can help to form a basis for assessing the effects of malocclusion on the dysfunction of chewing. In this way, Wickwire et al[43] verified that the chewing patterns in the primary dentition are composed of wider lateral movements in the opening compared with the closing phase. It is a feature that is more predominant with the hard bolus type of food.[39,43,46]

It is reasonable to assume that this trend towards wide lateral movements is associated with a flat posterior occlusion and the small overlap of the incisors.[35,44] In the permanent dentition this pattern is different, characterized by wide chewing cycles with predominantly lateral paths of closure, which are closely related to improved masticatory performance, in accordance with Wilding and Lewin.[47] Positive significant correlation between lateral chewing motions and masticatory performance was also observed by Julien et al[13] The chewing cycle appears to increase the lateral component of movement when increased chewing efficiency is required, and increasing the lateral component of the chewing pattern increases the gliding contacts, which were considered the most important portion of the chewing cycle.[16]

In this study, the range of overbite in children with normal occlusion was 1-3 mm. Such a shallow overbite could influence lateral excursions, since overlap of the incisor is an important determinant of the excursion, and since masticatory movement in the primary dentition is more horizontal and more forward with small descend.[44] Taking this into account, further studies are necessary to prove that such pattern of chewing movements, associated with the number and distribution of occlusal contacts in primary dentition, should be considered as influencing factors in masticatory efficiency.

Multiple regression showed that particle size was not related to weight and height (Figs 1-4). Julien et al[13] verified that weight and contact area were closely related to particle size, heavier participants with larger contact areas had smaller median particle sizes. Other authors have found positive correlations in children between masticatory function and growth variables, such as body height and weight,[48,49] but it is important to remember that the samples of these studies are older than the sample of the present investigation. The effect of body weight on masticatory performance may be related to increased muscle mass during growth and to sex differences in muscle mass influenced by androgenic steroids.[37,50] Muscle mass comprises 45-50% of fat-free body weight and is closely related to age and body weight. Another measure of body size is the length of posterior ramus height, given that they grow and mature similarly.[13] Ramus height is related to bite force, being considered a mechanical efficiency factor. The amount of bite force a person can generate is the product of simple mechanical efficiency of the jaw system and size of the jaw elevator muscles. Rentes et al[51] found no differences in magnitude of bite force among children with normal occlusion, posterior crossbite and anterior open bite in the primary dentition. Considering these results and the small ramus height in the primary dentition, it makes sense to consider that the quality of occlusion in the primary dentition could influence masticatory performance to a greater degree than levels of bite force.

The possibility of sexual dimorphism in masticatory performance remains controversial. The results in relation to this variable were pooled in our sample because no significant differences between boys and girls were observed, a result also reported by Shiere and Manly[52] who found no differences in performance between boys and girls aged 12-14 years. Helkimo et al,[53] using almonds and the two-sieve method, also found no significant differences in performance between sexes in a large sample of 139 adults. In a study by Julien et al[13] the median particle size for adult males was approximately 0.9 mm, smaller than that of adult females and the differences between men and women were as great as the differences between women and girls. Wilding and Lewin[47] demonstrated a significant difference in median particle size of 0.3 mm between sexes when using Optosil. It is important to reinforce the difference that exists in muscle strength between males and females observed during puberty[37,50] that may explain the similar results between boys and girls at earlier ages, as reported here.

No unanimity has been achieved concerning the function of the masticatory muscles and its relation to sagittal deviations of the facial morphology. Most studies have not found any association between facial structure and bite force before adolescence. Due to the age range of our sample (3-5.5 years old) this variable was not considered in the present study. Ahlgren and Owal[54] found only slight or no differences in muscular function in patients with different sagittal patterns of facial morphology. They suggested that a longitudinal study to follow up each individual child during growth would be of interest to evaluate the importance of muscular influence on facial growth. Proffitt and Fields[55] hypothesized that the correlation between masticatory muscle force and facial form develops during adolescence and the increased ramus vertical height facilitates particle breakdown by allowing greater anterior and lateral mandibular crushing movements during power stroke.

With the aim to observe the electromyographic activity of masticatory muscles during mastication in crossbite, Ferrario et al[56] concluded that altered occlusal relationship influenced the coordination of the masticatory muscles during chewing and the functional alteration was more apparent when the side with the altered morphology was directly involved. Regarding children, few studies were performed in relation to electrical activity of their masticatory muscles and most of them related with normal occlusion in primary dentition.[45,57] Therefore the analysis of the masticatory muscle activity in altered occlusal relationship could provide useful data of the functional impact of morphological discrepancies. Besides this, the estimation of masticatory efficiency using EMG may be possible.[18,58,59]

Chewing places a functional demand on the stomatognathic system throughout life. A panorama view of changes during growth may give insight into naturally occurring relationships between form and function.[39] These changes could serve as a basis for accurately assessing the effects of malocclusion. Sound development of childhood occlusion is probably essential for the establishment of healthy occlusion in the permanent dentition, although the exact mechanism is not yet clear.[60] The findings of lesser masticatory efficiency in children with malocclusion may have influence upon the development of the stomatognathic system and may contribute to inadequate digestion, which is also related to how well the food is masticated and could have nutritional implications.

Although Group II was heavier than the other two groups, this factor does not signify that these children are healthier, since they may be eating foods with higher amounts of carbohydrates and which are easier to chew. Recognition of conditions that are known to interfere with the growth and development of a child should be considered and require careful diagnosis and treatment planning.[26] Since the three years prior to the initiation of the mixed dentition is a crucial period when normal changes of growth and functional adaptability occur, this is a time in which malocclusion may begin, and if not diagnosed and treated in time, may develop into a full-fledged malocclusion.[29]

Mauck and Trankmann[25] observed that patients treated successfully in primary dentition did not show any relapse to initial malocclusion, suggesting that changes in occlusion and mandibular position during treatment in this time are maintained in the mixed and permanent dentition, serving as a basis for physiological development of the dentition and craniofacial growth. In accordance with our results, children with normal occlusion comminuted better the Optosil tablet than children with posterior crossbite and anterior open bite, leading us to agree with the authors above, about early attention to malocclusion, focusing the normal development of stomatognathic system on both morphological and functional aspects.

Conclusions

1. The group with normal occlusion fragmented tablets into a greater number of particles of smaller sizes than the groups with malocclusion, signifying that occlusion may be an influencing factor in masticatory efficiency.
2. There was no significant difference between the group with crossbite and the group with open bite.

3. The body variables, weight and height, did not correlate with masticatory efficiency in the age group studied.
4. Since morphological and functional aspects of primary dentition could be influencing factor upon the development of the stomatognathic system, early attention should be given when alterations would be diagnosed.

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Abstract of the Scientific Literature

A Newly Recognized Syndrome of Skeletal Dysplasia with Opalescent and Rootless Teeth

A case report of a Thai girl presenting opalescent teeth, rootless teeth, hypodontia, large sella turcica, depressed and broad nasal bridge, disproportionately short stature, short neck, widely spaced nipples, broad chest, protruded abdomen, platyspondyly, and hypoplastic acetabulum. The author states that this combination of findings represent a unique and hitherto undescribed skeletal dysplasia and dental anomaly syndrome.

Comments: Pediatric dentists with an interest in skeletal dysplasia and dental anomalies like dentinogenesis imperfecta and dentin dysplasia will enjoy reviewing this case report. **MAB**

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A newly recognized syndrome of skeletal dysplasia with opalescent and rootless teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 92:303-7, 2001.

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