Original Article

Muscular Forces Exerted on the Normal Deciduous Dentition

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Abstract: This study evaluated the distributing characteristic of the forces exerting on the normal deciduous dentition and the relationship between the muscular forces, sex, and oral function. The pressure measurements were made with a computer-aided perioral force–measuring system designed by the authors. The forces were measured when the subject's head position was in a state of natural head position and oral function was at rest or with swallowing. The results indicated that the forces from lips, cheeks, and tongue at rest were about 37–208 N/m^2, whereas the pressure during swallowing was about 1009–1679 N/m^2. At rest, the pressure from lips and cheeks was higher than that from tongue ($P < .05$), whereas during swallowing, the lingual pressure was statistically larger ($P < .001$). A significant correlation existed between the muscular pressure and sex. When at rest, the boy's force from cheeks was higher than that of the girl's ($P < .05$) but during swallowing the boy's labial pressure was statistically higher than that of the girl's ($P < .01$). It was concluded that (1) the deciduous teeth are not in a state of absolute balance between external and internal forces, (2) the distributing manner and unbalanced mode of the forces are different with the different oral functions, (3) the lingual side of the mandibular anterior teeth endures great differences during oral functions and it may account for high incidence of malocclusion in this segment, and (4) a statistical difference between muscular forces and sex exists. (*Angle Orthod* 2005;75:785–790.)

Key Words: Perioral force; Deciduous dentition; Transducer

INTRODUCTION

Forces acting on the dentition are produced, principally, by perioral musculature and tongue. The forces play an important role in guiding teeth eruption and occlusion formation and maintaining dental arch shape and stability. The dentition is supposed to be in a state of balance between forces from the outside, the lips and cheeks, and forces from the inside, the tongue. During the past decades, a lot of devices[1–8] have been used to study these forces and some conclusions were made: that the position of the teeth was influenced by the forces developed by the soft tissues surrounding them and that there existed a dynamic equilibrium between forces from lips and cheeks and those from tongue. This dynamic balance would be different as oral functions change. However, many issues are still unclear.

First, the previous research only studied the pressure exerted on the mixed and permanent dentition,[1–11] but so far there is no corresponding study on the deciduous dentition. Muscle pressures can influence teeth position and dental arch stability. By exploring the deciduous muscle pressure, orthodontics could take some measures to interfere or even to stop malocclusion development from childhood.

Second, the relationship between the forces and sex is still unresolved. Thüer et al[7] thought female's force from lips was larger than male's. On the contrary, Kato

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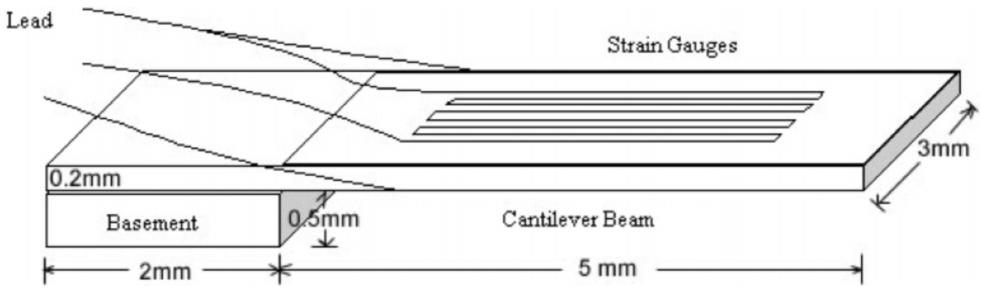

FIGURE 1. The sketch map of the transducer.

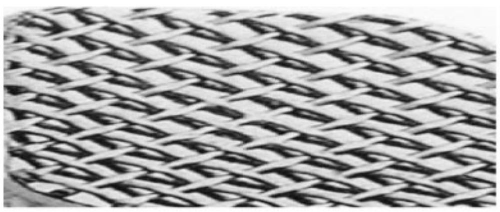

FIGURE 2. Web-shaped steel base.

FIGURE 3. Measurement of muscle pressure with the measuring system.

et al[8] and Yuan and Fu[9] concluded that male's force was greater than female's, and research of Li et al[10] asserted that there was no statistical variance between male and female.

Finally, much variation existed among these studies because of the different measurement techniques. This variation was related to the thickness of the intraoral transducer, which has substantial effects on the pressure measurement.[11] Lear et al[6] reported that even a 1.5-mm-thick transducer could cause an appreciable increase in mean forces. Gould and Picton[5] concluded that, to measure the correct pressure, the transducer should protrude less than one mm. Thüer et al[7] designed an extraoral pressure transducer incorporated in a water-filled system with an intraoral mouthpiece projected up to two mm from the surfaces of the teeth, but his calibration was too complicated. Takahashi et al[11] measured tongue pressure with a miniature pressure sensor incorporated in a custom-made one-mm-thick intraoral appliance. However, the appliance was so large that it occupied too much space. So it is necessary to design and develop a thinner miniature transducer with a more convenient measurement process.

Therefore, the purpose of this study was to apply a computer-aided muscular force–measuring system for the measurement of forces acting on the normal deciduous dentition and to discuss the distributing characteristic of the forces and to value the interrelation between the forces, sex, and oral functions.

MATERIALS AND METHODS

Subjects

Thirty-nine children (19 boys and 20 girls; mean age 4.96 years, SD 0.63; range 3.7 to 6.0) were investigated. The sample was selected, according to their order of arrival, from among those coming for routine oral examination or treatment at our department. The inclusion criteria were an intact deciduous dentition, normal incisor and molar relationship, no oral bad habits, and no history of orthodontic treatment.

Measurement apparatus and positions

A strain gauge computer-aided measuring device,[12] with a transducer thickness of only 0.7 mm, was used for the measurement. The transducer (Figure 1) comprised strain gauges and cantilever and was insulated with silicone rubber. The two 120-ohm strain gauges were respectively positioned on the upper and inferior surfaces of an Nb strip, which on its one end was welded with a multilay web-shaped steel base (Figure 2) to detect the distortion of the spring strip. The strain gauges were incorporated with two fine resistances to form a Wheatstone bridge circuit. The fan-out of this bridge was connected to PCLab biological signal collecting-processing system (Beijing Microsignalstar Technology Company, Beijing, China) to comprise this computer-aided muscular pressure–measuring system (Figure 3). The device had been studied in vitro with little drift and mechanical lag and nice linearity of the load-strain curve, whereas the transducer bears the pressure from 0 to 50,000 N/m^2.[12]

FIGURE 4. Transducer used in the labial surface of the upper incisor.

The transducers were cemented to the central surfaces of the teeth with Jing-jing enamel adhesive (Tianjing Synthesizing Material Institute, Tianjing, China). Afterward, all the transducer's leads were bunched and emerged between the lips at the corner of the mouth (Figure 4). The surfaces were at the following positions: (1) labial surface of the upper left incisor (LaUI), (2) buccal surface of the upper left molar (BUM), (3) labial surface of the lower left incisor (LaLI), (4) lingual surface of the lower left incisor (LiLI), and (5) lingual surface of the lower left molar (LiLM).

Natural head position registering method

To achieve natural head position (NHP), the subjects were asked to be seated in the dental chair in front of a mirror.[13,14] They were asked to look into a mirror image of their eyes, after tilting their head up and down with decreasing amplitude until they felt that they were relaxed. The mirror was positioned 200 cm in front of the subject. When the individual's NHP was achieved, he or she was asked to do corresponding activities to record the forces.

Measuring procedure

The pressure was measured in the following order: LaUI, BUM, LaUI, LiLI, and LiLM. For each placement of the mouthpiece, registrations were done in the rest position, during swallowing of water, and then repeated in this order three times. For the water-swallowing test, the child was given a teaspoonful (three mL) of water in his or her mouth and asked to swallow on command. At rest, the device would record the resting pressure, and during swallowing, the device would mark down a swallowing pressure wave. Then the maximum value of this pressure wave was used as the functional pressure. Last, the mean values were calculated for the three repetitions of the two experimental tasks and then these intraindividual mean values were used for further statistical evaluation.

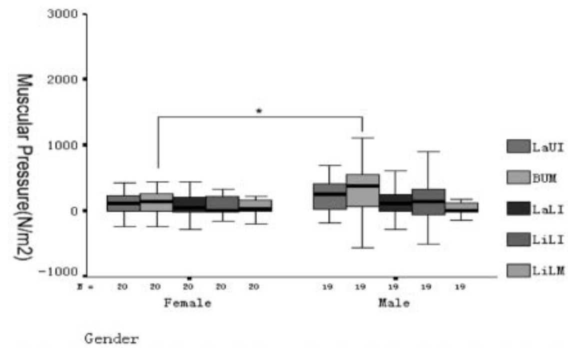

FIGURE 5. Comparisons of the muscle pressure and sex at rest.

All recordings were repeated in a later session. The time interval between the two recording sessions varied between one and 21 days.

Statistical analysis

All data were entered into a computer database and SPSS (SPSS 10.0 for Windows, Statistics Package for Social Science, SPSS Inc., Chicago, Ill) was used to perform the statistical analysis. The median, maximum, and minimum for each variable were calculated.

Systematic differences between the variables recorded at the first and second recording sessions were tested with a paired *t*-test. The standard deviation of the single observations (s_i) was calculated from the duplicate determinations (recordings at sessions 1 and 2) with the formula[15] $s_i = \sqrt{\sum d^2/2n}$ where d is the difference between the two determinations.

Differences between male and female groups or between oral functions were tested with Mann-Whitney *U*-test. Differences between tooth positions were tested with Kruskal-Wallis *H* test. Significance was established at the 5% level.

RESULTS

Muscle forces and sex

The median resting forces (Figure 5) from LaUI, BUM, LaLI, LiLI, and LiLM for boys were 259, 375, 118, 148, and 0 N/m^2, respectively, whereas at the same time for girls, the median values were 114, 151, 53, 0, and 41 N/m^2, respectively. As shown in Figure 5, a tendency existed for a larger muscle pressure at rest for the boys than the girls, especially for the site of BUM ($P < .05$).

On the other hand, during swallowing, the muscular pressure of both sides of the dental arch increased rapidly for the boys and girls (Figure 6). The median values for the boys were up to 1371, 1457, 1513, 2149, and 2945 N/m^2 in the order of LaUI, BUM, LaLI,

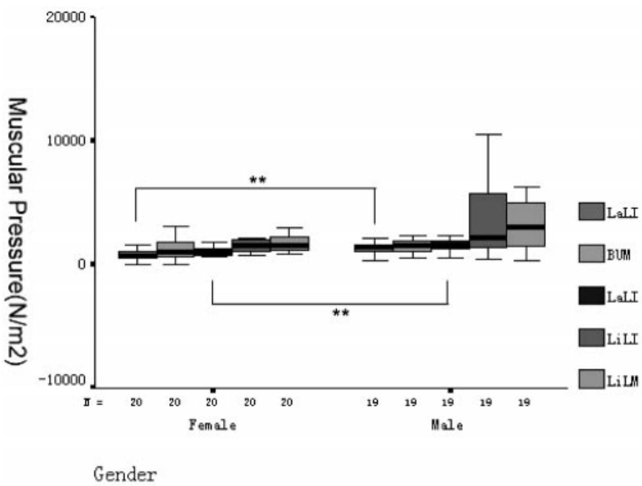

FIGURE 6. Comparisons of the muscle pressure and sex during swallowing.

TABLE 1. Relationship Between the Muscle Pressure (N/m²) and Measuring Site at Rest[a]

Measuring Site[b]	Muscle Pressure at Rest	
	Median	Min-Max value
LaUI	148	−473–1020
BUM	208	−557–1112
LaLI	93	−417–1482
LiLI	37	−486–1388
LiLM	37	−280–1481

[a] H = 9.633; $P < .05$.
[b] LaUI indicates labial surface of the upper left incisor; BUM, buccal surface of the upper left molar; LaLI, labial surface of the lower left incisor; LiLI, lingual surface of the lower left incisor; LiLM, lingual surface of the lower left molar.

LiLI, and LiLM and for the girls, they were 665, 986, 944, 1485, and 1512 N/m², respectively. The figure shows the same tendency that during swallowing the boys' pressure was larger than the girls', especially for the sites of LaUI and LaLI ($P < .01$).

Muscle forces and teeth positions

The resting muscular pressure among these five sites was about 37−208 N/m² (Table 1). The highest rest pressure was found in the site of BUM whereas the lowest rest pressure was in the sites of LiLI and LiLM. For every measurement site, negative pressure can be recorded. The upper lip pressure was negative in four children (10.26%). The pressure from the cheeks was negative in five children (12.82%), and there was negative pressure in the sites of LaLI, LiLI, and LiLM in seven children (17.95%), respectively.

In contrast, the swallowing pressure was about 1009−1679 N/m² (Table 2). The highest pressure was recorded in the site of LiLI whereas the lowest pressure was at LaUI and LaLI. There was no negative pressure on the lingual side of the lower teeth, but a negative upper lip pressure and a negative cheek pressure (2.56%) were recorded and two (5.13%) found in the lower lip.

TABLE 2. Relationship Between the Muscle Pressure (N/m²) and Measuring Site During Swallowing[a]

Measuring Site[b]	Muscle Pressure During Swallowing	
	Median	Min-Max value
LaUI	1009	−56–2747
BUM	1310	0–5747
LaLI	1253	−46–4344
LiLI	1679	407–16,494
LiLM	1646	324–6214

[a] H = 28.107; $P < .001$.
[b] LaUI indicates labial surface of the upper left incisor; BUM, buccal surface of the upper left molar; LaLI, labial surface of the lower left incisor; LiLI, lingual surface of the lower left incisor, LiLM, lingual surface of the lower left molar.

Muscle forces and oral function

Tables 1 and 2 show that the forces are different with the different oral functions. First, the median values were different for those at rest, and the pressure exerted on the deciduous arch was little, whereas during swallowing, the pressure was significantly large ($P < .001$), especially for the lingual surface. Second, the distributing characteristic of the forces varied with the oral functions. While at rest, the pressure from lips and cheeks was larger than from the tongue ($P < .05$). On the contrary, during swallowing, the pressure acting on the lingual teeth surfaces was more than that on the labial and buccal teeth sides ($P < .001$).

Reproducibility and interindividual variance

Data from the first and second recording sessions in the five positions was tested and no significant difference was found ($P > .05$). That is to say, the intraindividual pressure was stable and reproducible. However, large variance existed for interindividual data (Tables 1 and 2).

DISCUSSION

Influence of the thickness of the transducer

To measure the forces, many devices have been designed and all of these devices had different thicknesses of the transducers, which can encroach upon the space normally occupied by lips, cheeks, or tongue and therefore had a potential effect on the measurement.[3–11,16]

Weinstein et al[1] demonstrated that the soft tissue force would change and make the teeth move if the teeth-buccolingual dimension were increased. In fact, the transducer did increase the teeth dimension and influenced the tension of the proximate muscles. Many scholars had studied this influence and tried to decrease the added bulge,[5–7] but thus far the thickness of the mouthpiece is often not less than one mm.[11]

In this study, the thickness was only 0.7 mm, and it was the thinnest transducer that can cater for the result of Gould and Picton.[5] With its small dimension, our measuring device best suited the measurements, especially for deciduous dentition.

Muscle pressure

This study indicated that at rest the perioral forces were larger than the tongue pressure ($P < .05$), and during swallowing, the force from the inside was larger than from the outside ($P < .001$) and the lingual force increased greater than the labial side. Therefore, teeth have been encountering great change during oral functions, especially for the lower incisors. As shown by our results, the greatest variable site was LiLI, which was subjected to diversity from 37–1679 N/m^2. This diversity maybe suggest that malocclusion, such as crowding, often occurs in the anterior teeth of the mandible.

Negative pressure was recorded in this study, which was in accordance with previous observations.[7,11,17–20] Faigenblum[19] and Thuer et al[20] recorded negative pressure at the palatal vault. It is possible that such pressure could spread also to the vestibular fold and be maintained during lip closure. With the help of the negative pressure, the forces would tend to pull a transducer away from the teeth surface rather than exert pressure.[18]

Large interindividual variation is a common finding in studies of muscle pressure.[7–11,17] It would be very difficult to control the interindividual variation because of the varied functional response among individuals. Bundgaard et al[21] stated that similarities in occlusion and facial morphology do not account for similarities in functional pattern. So Thüer et al[7] pointed out that the variation was likely to be of a biological nature and not because of recording difficulties, and Luffingham[22] also concluded that the variation probably arose from a change in subject behavior rather than being because of methodological difficulties.

Male vs female differences

The relationship between perioral forces and sex still remains unclear.[7–10] Thüer et al[7] found for normal incisor relationship individuals, the upper lip swallowing pressure tended to be higher in girls than in boys, but for those with varying types of malocclusion, lip pressure had no sexual variance.[17] However, Kato et al[8] and Yuan and Fu[9] compared Japanese and Chinese samples, respectively, and found obvious variance between forces and sex. That is to say, male's perioral forces was larger than female's.

In the present study, the trend was found that at rest, the boys' muscle pressure at the five sites was greater than the girls', especially for the site of BUM ($P < .05$). Meanwhile during swallowing, the boys' labial forces were significantly greater than the girls' ($P < .01$). Our study was in accordance with Kato et al[8] and Yuan and Fu[9] results.

Muscle forces and dentition dynamic equilibrium

Dentition dynamic equilibrium has been of concern for ages. It is believed that this equilibrium can influence the position and stability of the teeth. As the first measurement on the deciduous dentition, this study indicated that under NHP there exists an unequal situation between the two sides of the dental arch during oral functional activities.

Because there is no data regarding the predeciduous dentition, the effect of the musculature on the growth and development of the dental arch and jaws remains vague. It is well known that form and function is a cause-effect relationship so we can put forward a hypothesis that during the whole process of skeletodental growth and development, the dynamic equilibrium based on the perioral muscles and the tongue is different. At the stage of the preprimary dentition, the tongue fills the whole oral cavity and the lingual force is much greater than the perioral forces, which can be in favor of the expansion of the skeletodental form. With the expansion of the jaws, enlargement of the oral cavity and eruption of the teeth, the tongue relatively recedes and the swallowing pattern changes from a baby's swallow to an adult's swallow gradually so that the lingual forces tend to weaken. At the same time, muscle function becomes stronger and stronger because of the needs of mastication and expression so that the pressure from the lips and cheeks tends to strengthen. Therefore, the power of expanding the skeletodental form is weakening and until to adult the forces between these muscle groups are in a state of dynamic equilibrium and the skeletodental form tends to be stable subsequently. Certainly, further study is needed to evaluate this tendency.

CONCLUSIONS

From the present study, the following conclusions can be made: (1) when at rest, significant sex differences exist in the site of BUM, (2) when at rest, forces from lips and cheeks are statistically larger than that from tongue, (3) during swallowing, statistical sex differences exists on the labial side of the upper and lower anterior teeth, (4) during swallowing, forces from lips and cheeks are statistically less than that from tongue, and (5) the forces are different with the differences of sex and oral functions. The lingual side of the mandibular anterior teeth endures great differences during oral functions, which may account for high incidence of malocclusion in this segment.

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