Comparative clinical study evaluating lip-closure forces in association with tongue pressure in children

Yasuhiro Shiono[a], Kazumasa Morikawa[a], Kenshi Maki[a]

[a]Division of Developmental Stomatognathic Function Science, Department of Growth and Development for Function, Kyushu Dental University, 2-6-1 Manazuru Kokurakita-ku,Kitakyushu-City, Fukuoka, 803-8580, Japan

Objective: The aim of this study was to examine the relationship between lip closing forces and tongue pressures in children with normal and reverse occlusions.

Study design The subjects were pediatric 30 patients treated at the Kyushu Dental University hospital. Their age range was eight to 11 years and they were considered old enough for measurement with a multidirectional lip-closing force measurement system. Fifteen patients had normal occlusions and 15 had reversed occlusions. A multidirectional lip-closing force measurement system was used to determine lip pressures. To evaluate tongue motions, tongue movements to the palate were evaluated using a tongue pressure scale.

Results The average total lip closing force in subjects with normal occlusions was 5.031 ± 1.629 (N·S) and that in subjects with reversed occlusions was 2.770 ± 1.167 (N·S).

There was a slight correlation between tongue pressures and total lip closing forces.

Conclusions The lower lips are dominant in lip closings in children with normal occlusions, while the upper lips are dominant in those with reversed occlusions. This study demonstrated a weak correlation between lip closing forces and tongue pressures in the normal and reversed occlusion groups.

KeyWords lip closing force, tongue pressure, reversed occlusions

1. Introduction

The relationship between malocclusion and the oral circumference of the area of soft tissue has been studied, while various reports of lip closure have also been presented, including studies of patients with Class III malocclusion and lip closing[1, 2, 3, 4]. Sivakumar[5] and Sabashi[6] noted an association between nasal obstruction and lip closure. Furthermore, Nakatsuka[7], Amerman[8], and Wood[9] showed methods to evaluate lip closing forces and reliability. However, few studies have determined lip closing abilities in several directions in children, with the exception of the report by Ooishi[10]. Kawamura[11] focused on tongue motions and malocclusions, while Fei[12] investigated the association between gender or posture and tongue motions. In the present study, we examined the characteristics of lip closing forces in children and the

association of tongue elevation motions and lip closing forces in children with normal and reversed occlusions.

2. Subjects and methods

2.1 Subjects

The subjects included children treated at the Kyushu Dental University hospital. The measurer explained the purpose of the study to both parents and their children, and subjects were enrolled after receiving consent. Their age range was eight to 11 years and they were considered old enough for measurement with a multidirectional lip closing force measurement system. Fifteen children (8 boys and 7 girls) had normal occlusions and the remaining 15 (9 boys and 6 girls) had reversed occlusions. The diagnostic criteria for malocclusion is described in Table 1[13]. This study excluded subjects who were using or had used removable orthodontic or fixed devices. In addition, those with skeletal reversed occlusion who could not engage their incisor teeth were also excluded.

This study was approved by the Committee for Clinical Research of Kyushu Dental University(approval number 12-34).

2.2 Measurement of lip closing forces

A multidirectional lip closing force measurement system (PROCEED, Nagano) was used to determine lip pressures. The measurements were performed according to the method of Ooishi[10] who used the same device. All subjects sat in a relaxed position and were measured with a probe in their mouths in a manner such that the Camper planes were parallel to the floor (Fig.1). To keep the subjects' attention in a frontal direction, a marker was placed on the wall, and they were asked to continue looking at it during the measurement period (Fig. 2). To evaluate lip closing forces, the measurements were done for 30 s according to the method of Ooishi[10]. The children were asked to strongly purse their lips 3 times for 4 s each and the resulting waveforms were measured. The measurer chose the most stable recorded waveform and calculated the impulses from 1–2 s after the undulating output initiation; this value was defined as the lip closing force for each subject. In the present study, the measurer analyzed force in 8 directions obtained with a mensuration probe. The probe and positions of the 8 channels are shown in Fig. 3. This study defined the sum of lip closing force from 8 directions as the total lip closing force. In subjects with reversed occlusions the range of total lip closing forces was from 1.001 to 4.680 (NS) and those

with normal occlusions ranged from 3.110 to 4.680 (NS). There were large variations for both measurements. Therefore, this study defined the lip closing force as the value obtained by dividing each impulse in its respective channel into the sum of impulses in 8 directions.

Prior to the measurement trial, 5 children were chosen at random with ages representing those of the subjects. Within an interval of a few days, measurements were performed twice in those subjects. No significant difference in lip closing force was noted between the first and second measurements in these subjects (Table 2).

2.3 Measurement of tongue pressures

To evaluate tongue motions, tongue movements to the palate were evaluated using a simple type tongue pressure scale. Hayashi[14] noted that the advantage of a simple type tongue pressure scale was the lack of unwanted side effects associated with radiation exposure that may result from radiographic-measurement methods. This scale is not a complicated device and is convenient to use. Tongue pressures were measured using a JMS tongue pressure scale (GC, Tokyo)[15]. Prior to starting the measurements, each subject sat in a chair in a relaxed position and the procedures were repeated. According to the reports of Tamura[16] and Dietsch[17], positional

changes of the vertical jaw have an influence on tongue movements. The measurer maintained the Frankfurt plane of each subject approximately parallel to the floor and measured tongue pressures (Fig. 4). After pressure regulation on a measurement balloon, each subject pressed the measurement balloon with their tongue at maximal force while grasping the hard ring of the tongue pressure probe with their front teeth. Measurements were performed 3 times, with an average of each largest value used as the tongue pressure. Each measurement period was for 30 seconds in consideration of muscular fatigue. Prior to these measurements, five subjects were again chosen at random to represent the same ages as the subjects and the same measurements were performed twice with an interval of a few days. No significant difference in tongue pressure was found between the first and second measurements (Table 2).

2.4 Data analysis

Lip closing forces from channels 1–8 were determined, with differences between the channels examined using multiple comparison testing by the Scheffe method. In addition, the Student's t-test was used for comparison of lip closing forces and tongue pressures measured on the same channel in subjects with normal and reversed occlusions. Spearmen's coefficient of correlation (r) was used to correlate lip closing

forces with tongue pressures. All statistical analyses were performed using Microsoft Excel 2007 (Microsoft Tokyo) and SPSS for Windows 17.0 (IBM JAPAN, Tokyo).

3 Results

The average total lip closing force in subjects with normal occlusions was 5.031 ± 1.629 (NS) and in those with reversed occlusions was 2.770 ± 1.167 (NS)(Table3).

The values at channel 5 were greater than that at channel 1 in normal occlusion subjects, while the values at channel 1 were greater than that at channel 5 in subjects with reverse occlusion. A comparison between the same channels in subjects with normal and reversed occlusions revealed significant differences for channels 1–8, excluding 3 and 7, however, which suggested a horizontal direction(Table4).

Results of multiplex testing between each channel in subjects with normal and reversed occlusion are shown in Table5. For normal occlusion, there were no significant differences between channels 2 and 4, 2 and 6, 2 and 8, 3 and 7, 4 and 6, 4 and 8, and 6 and 8.As with subjects with normal occlusions, there were no significant differences between the same combination of channels in subjects with reversed occlusion.

A comparison between tongue pressures and total lip closing forces in subjects with normal and reversed occlusions is shown in Fig. 5. The average value for tongue

pressure in normal occlusions was 27.24 ± 7.19 kPa and in reversed occlusions was slightly greater at 29.22 ± 6.85 kPa(Table3), but the difference was not significant (P > 0.05). The values obtained in Spearman's rank correlation coefficient findings for total lip closing forces and tongue pressures for subjects with normal and reverse occlusions were r= 0.347 and r= 0.365, respectively. For both groups, there was a slight correlation between tongue pressures and total lip closing forces.

4 Discussion

4.1 Lip closing force

This study investigated eight to 11 year old children with both normal and reversed occlusions by determining tongue pressures, and lip closing forces with an azimuthal angular measurement method. The sum of the impulses of lip closing forces in eight directions in subjects with normal occlusions was significantly greater when compared to those with reverse occlusions (5.031 ± 1.629 [NS] vs. 2.770 ± 1.167 [NS]).

A study by Yoshida[18] of changes in lip closing forces in the vertical direction during childhood found age-associated increases. In the present study, the average age of the normal occlusion group was 9.2 ± 0.7 years, while that in the reversed occlusion group was 9.0 ± 0.6 years. We concluded that this small age difference did not have an

influence on the difference between the groups. According to Ono[19], lip closing forces vary in children of the same age according to the amount of malocclusion. Our findings support the results of Ono. In another report, Murakami[20] noted that adult men had significantly greater lip closing forces in multiple directions when compared to adult women. However, there were no significant differences between boys and girls in this study. We intend to continue our investigations in the future with a larger sample size.

Channels 1, 2, and 8 were used to indicate pressures from the upper lips, which were considered to indicate the labial positions. Channels 4, 5, and 6 were considered to reflect pressures from the lower lips. There were no lip closing forces detected in channels 3 or 7. These results were similar to those presented by Ooishi[10] and Yamaguti[21] which were obtained using a PROCEED multidirectional lip-closing force measurement system. When children purse their lips, the orbicularis oris muscles surrounding their mouths in the form of a belt shrink. The muscle bundle of the orbicularis oris mixes and ends at the angle of the mouth forming the shape of a node. The node plays the role of a fulcrum in muscle contraction. That is the reason why no lip closing forces were detected in channels 3 and 7.

4.2 Comparison of lip closing forces at each channel in normal and reversed occlusion

When the measurer compared lip closing forces from the eight channels from subjects with normal occlusions and those with reversed occlusions, significant differences were found in the readings from channels 1, 2, 4, 5, 6, and 8. Subjects with reversed occlusions showed larger values at channels 1, 2, and 8, while those with normal occlusions had larger values at channels 4, 5, and 6. As noted above, when children purse their lips, the lower lips were dominant in those children with normal occlusions, while the upper lips were dominant in those with reversed occlusions. Naruse[22] performed an analysis of muscle activity around the oral cavity using electromyogram topography. It was reported that with pouting lips, subjects with normal occlusions show the greatest amount of muscle discharge with the lower lips. In subjects with reversed occlusions muscle discharge is seen in the areas under the nose and upper labial part. Our results are in agreement with those results. A portion of the maxillary orbicularis oris muscle is attached to the nasal septum near channel 1 and it plays the role of a fulcrum in muscle contraction at the angle of the mouth. This is a reason that maxillary lip closing forces had values smaller than those for the mandibles in a study of children without malocclusions. In contrast, in a study of children with reversed occlusions, the closing forces of the upper lips were larger than that of the lower lips[23]. Those results also showed that in children with reversed

occlusions (class III), pressure from the upper lips was relatively high and the tongues were at low positions, resulting in maxillary regression and undergrowth. Our results support the proposal of Frankel regarding multidirectional lip closing forces in children with reversed occlusion[23]. Recently, the Mu-shield used for early clinical treatment of reversed occlusions has been reported by Ohki[24], Nakahara[25], and Yamaki[26]. This study suggests that this appliance can be effective in reducing strong upper lip pressures and promoting maxillary growth in children with reversed occlusions.

4.3 Comparison between each channels using multiplex testing

Results of multiplex testing among each channel which focused on the median, horizontal, and center lines of the measurements showed no significant differences between children with normal or reversed occlusions. The combination of channels for subjects with reversed and normal occlusions was the same for both. As for the median line, there were no significant differences between the readings from channels 2 and 8, 4 and 6, and 3 and 7. The last set could be explained as being due to only slight closing forces. Our results suggest that lip closing forces occur equally on the right and left towards pars centralis when children pucker their mouth, because there were no significant differences between channels 2 and 8, and 4 and 6. However, there was a

significant difference between channels 1 and 5 with regards to the horizontal line. This results suggests that when children pucker their mouths, horizontal imbalances of lip closing forces occur. The measurer asked the present subjects to pucker their mouths again after measuring and observing them from the front. Our observations confirmed upwards labial position movements in those children with normal occlusions. In addition, the measurer found labial position movements to the lower parts or upwards in children with reversed occlusions. No labial movements to the right or left were noted, whereas movements to the top and bottom were observed. These results suggest that an imbalance of lip closing forces occur vertically when children pucker their mouths.

Minakuchi[27] investigated movement of soft tissues around the lips using a 3D anthropometry system. According to that report, soft tissue surrounding the lips moved upwards in a person with normal occlusion, which is considered the same movement as the labial movement observed in the present study. Our results suggest that when children with reversed occlusions pucker their mouths, the lips become displaced downwards during exercise. In the study of Minakuchi, there were no subjects with reversed occlusions. However, we intend to evaluate the movement of soft tissue in the circumference of the lips in a future study. The relationship between channels in

slanted directions showed no significant differences between channels 2 and 6, and 4 and channel 8. These results suggest that when children pucker their mouths, balanced closing forces in a slanted direction occurs with exercise.

4.4 Comparison of tongue pressures

The average value for tongue pressure in children with normal occlusions was 27.24 ± 7.19 kPa, while that in children with reversed occlusions was 29.22 ± 6.85 kPa(Table 3). Both were lower when compared with the report of Utanohara[15], who examined adults using the same scale. In our study, there were no significant differences for tongue pressures between subjects with normal and reversed occlusions. On the other hand, the tongue pressures needed to push the palates in subjects with reversed occlusions were stronger than those with normal occlusions.

Misiro[28] measured oral muscle pressures in children with normal occlusions and in those with mandibular protrusions. It was found that tongue pressures to the palate were greater in children with mandibular protrusions. Brodie[29], Winders[30], and Turlley[31] also found that tongue pressures to the front teeth area of the alveolus were greater in subjects with mandibular protrusions. Our results are in agreement with those reports.

In clinical findings, the tips of the tongues at rest are located near the cervix of the maxillary front teeth (termed the spot) in children with normal occlusions. In those with reversed occlusions, the tongues are in a low positions and it is difficult to hit the spots. The present tongue pressure measuring system determines pressure while the test subject pushes a balloon attached to the front of the probe with the tongue. This balloon has a certain thickness and can fill the narrow oral cavities of children. Therefore, in children with reversed occlusions and low positioned tongues, it was indicated that high tongue pressures were observed in association with the palate, balloon, and tongue positions. Other evaluation methods, such as a procedure using a rubber sensor reported by Makihara[32] or that using a sensor sheet noted by Hori[33], were used for tongue evaluations. We intend to examine methods for measurements and measurement positions to further evaluate tongue function in a future study.

4.5 Correlation of tongue pressures with lip closing forces

We also evaluated the present subjects with normal and reversed occlusions by measuring the correlation of tongue pressures with total lip closing forces using Spearman's rank correlation coefficient. That value in normal occlusion was $r= 0.347$ and in reversed occlusion was $r= 0.365$. The correlation between tongue pressures and

total lip closing forces were low in both cases. Both groups of muscles constituting the tongue and the orbicularis oris are skeletal muscle tissues, and thought to show a general type pattern of development as determined by the Scammon curve. Yoshida[18] stated that lip closing forces in children increase with age, while tongue pressures in the palatal direction are thought also to increase with age. This might be one reason that a relationship was found between lip closing forces and tongue pressures in children. Lambrechts[34] and Frankel[35] reported an association between lip closings and tongue pressures from the viewpoint of malocclusions. The tongue functions in formation and transport of the alimentary bolus, as well as pronunciation and deglutition, both of which are composed of very complicated motions. We hope to evaluate tongue functions in detail in a future study and also determine its association with lip closing forces.

5 Conclusion

Lower lips are dominant in lip closing in children with normal occlusions, while upper lips are dominant in those with reversed occlusions. In addition, we found a weak correlation between lip closing forces and tongue pressures in the normal and reversed occlusion groups.

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Figure Legends

Fig.1.Instrumentation of the multidirectional lipclosing force measurement system

Fig.2.Placement of the marker on the wall

Fig.3.Radar chart of 8 directional lip closing forces

Fig.4.Measurement of tongue pressureFig.5. Comparison of tongue pressures and total lip closing forces

Table 1. Diagnostic criteria for malocclusion

Normal occlusion Overjet of <5 mm, upper incisors cover less than the vestibular surface of teeth for half of the lower incisors, upper jaw incisors engage the lower jaw incisors
Reversed occlusion Minus overjet for 4 incisors in upper and lower jaws

Lip closing force			Tongue pressure		
Measurement period	First	Second	Measurement period	First	Second
Subject			Subject		
①	3.11	3.37	①	41.0	41.4
②	6.20	6.07	②	30.7	30.5
③	4.30	4.48	③	25.1	29.1
④	2.08	2.04	④	37.2	39.9
⑤	4.68	4.04	⑤	38.1	41.0
Average (NS)	4.07	4.00	Average (kPa)	34.4	36.4
S. D	1.40	1.32	S. D	5.7	5.4
Variation coefficient (%)	4.3		Variation coefficient (%)	4.2	

Table 2. Changes in lip closing forces and tongue pressures in 5 children

	Normal occlusion	Reversed occlusion
Total lip closing force（NS）	5.031±1.629	2.770±1.167
Tongue pressure（kPa）	27.24±7.19	29.22±6.85

Table 3. Total lip closing force and Tongue pressure

Table 4. Average lip closing force at each channel

	ch 1	ch 2	ch 3	ch 4	ch 5	ch 6	ch 7	ch 8
Normal occlusion	0.251±0.058 *	0.085±0.044 *	0.004±0.001	0.125±0.054 *	0.335±0.040 *	0.116±0.027 *	0.003±0.005	0.083±0.030 *
Reversed occlusion	0.301±0.032	0.118±0.019	0.006±0.010	0.090±0.044	0.221±0.043	0.080±0.025	0.009±0.021	0.145±0.037

*：$p < 0.05$

Table 5. Multiplex testing at each channel

Normal occlusion

	ch 1	ch 2	ch 3	ch 4	ch 5	ch 6	ch 7	ch 8
ch 1								
ch 2	*							
ch 3	*	*						
ch 4	*	ns	*					
ch 5	*	*	*	*				
ch 6	*	ns	*	ns	*			
ch 7	*	*	ns	*	*	*		
ch 8	*	ns	*	ns	*	ns	*	

Reversed occlusion

	ch 1	ch 2	ch 3	ch 4	ch 5	ch 6	ch 7	ch 8
ch 1								
ch 2	*							
ch 3	*	*						
ch 4	*	ns	*					
ch 5	*	*	*	*				
ch 6	*	ns	*	ns	*			
ch 7	*	*	ns	*	*	*		
ch 8	*	ns	*	ns	*	ns	*	

*Significant difference

ns: No significant difference

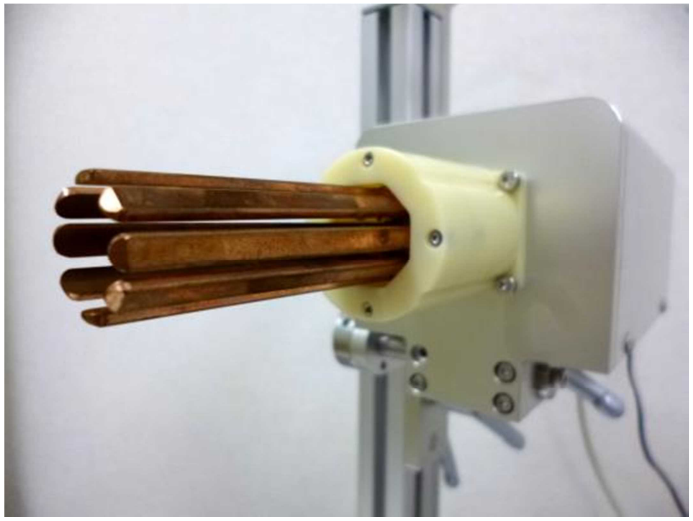
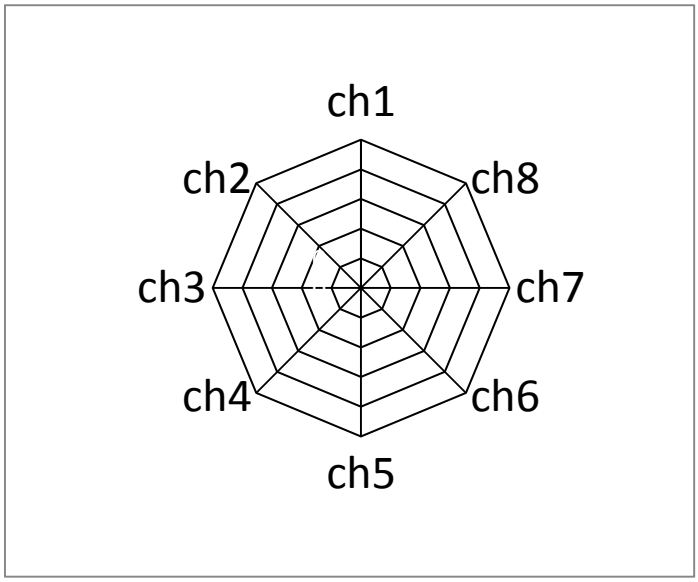


Fig. 1. Instrumentation of the multidirectional lip closing force measurement system

Fig. 2. Placement of the marker on the wall



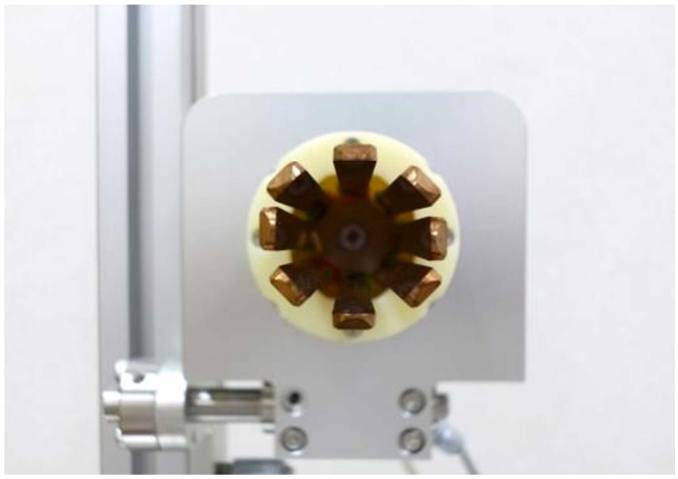


Fig. 3. Radar chart of 8 directional lip closing forces

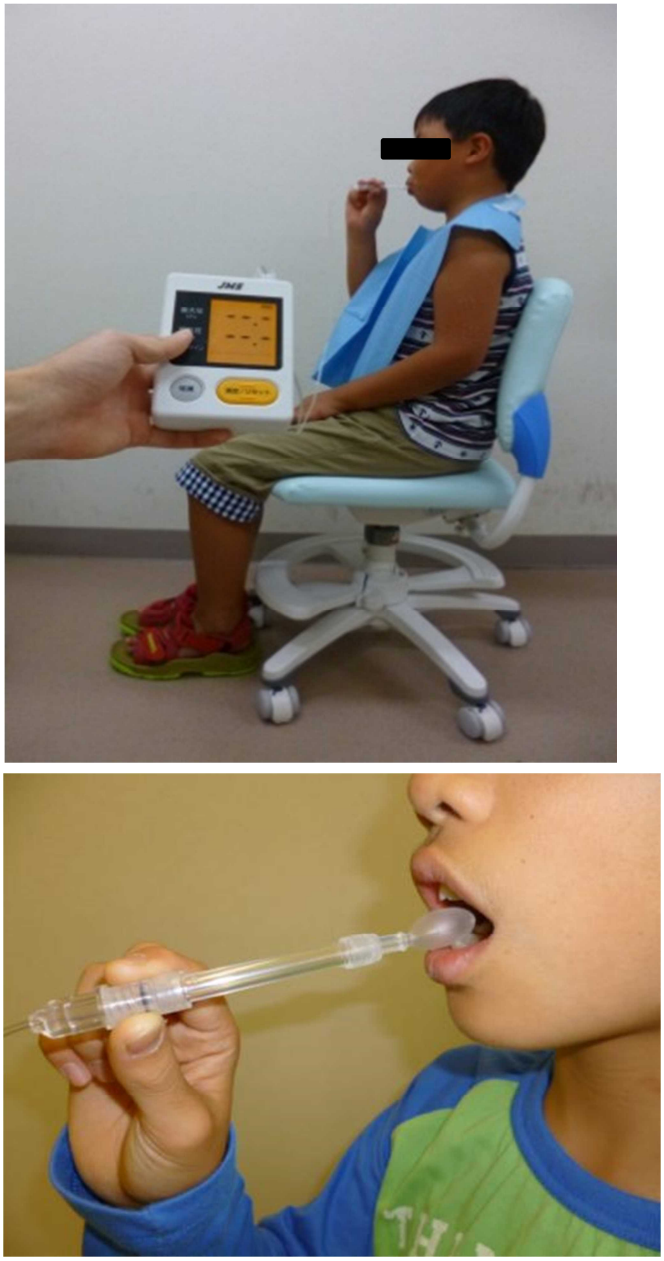


Fig. 4. Measurement of tongue pressure

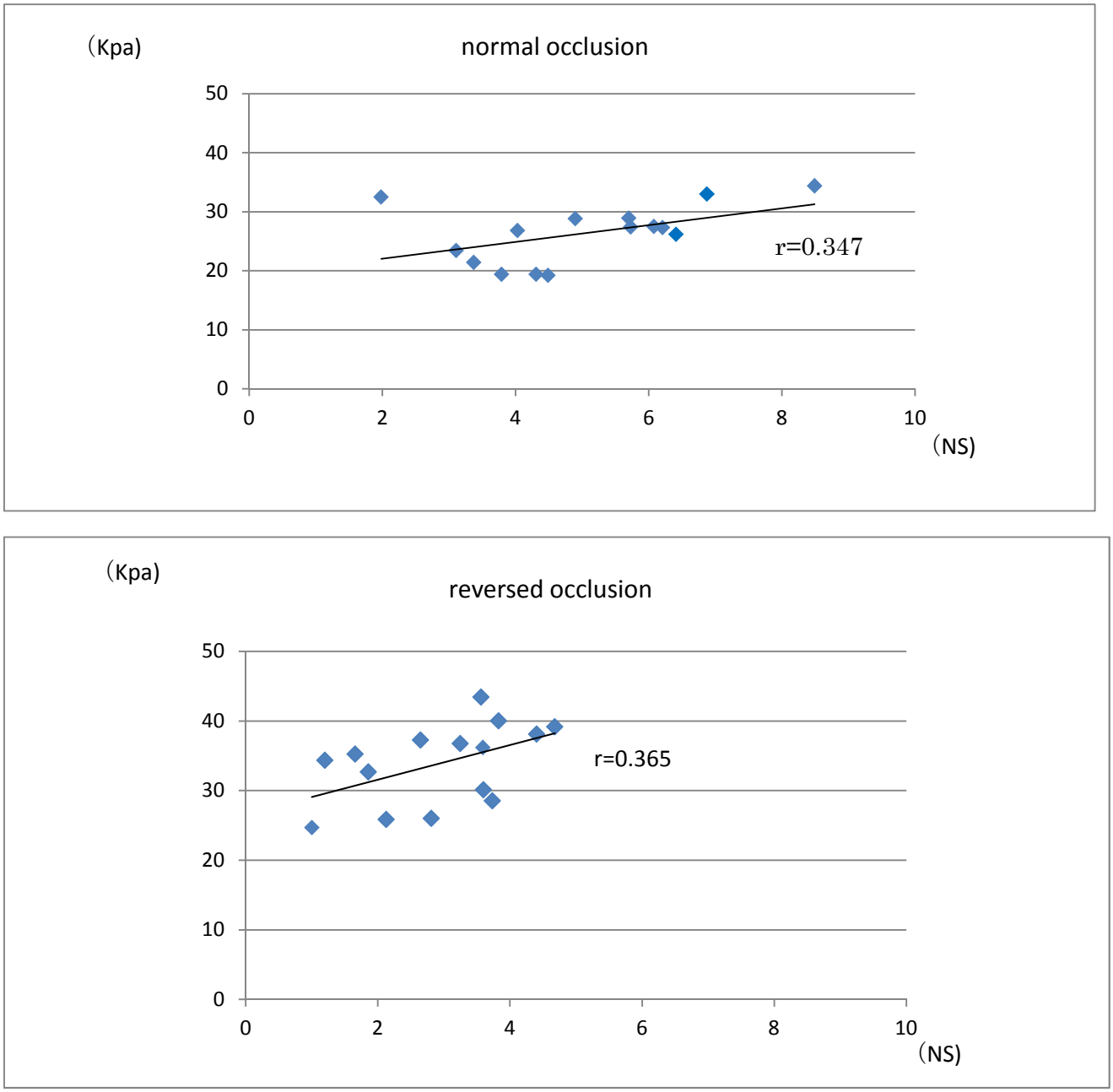


Fig. 5. Comparison of tongue pressures and total lip closing forces