# Correlation Between Functional Lingual Pressure and Oral Cavity Size

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The hypothesis that pressure by the tongue and lips influence the development of the dental arch and the whole oral cavity is an old one. The "functional matrix" view of facial growth (*5*), which emphasizes functionally-related growth of the orbit, nasal cavity, oral cavity, etc., provided a conceptually new way of looking at form-function interaction. More recently, several writers (*1, 7, 9*) have expressed the view that resting pressures are more important in determining dental arch form than are functional pressures from such activities as speaking and swallowing. Proffit, Chastain and Norton (*8*) found, for instance, no relationship between increments of lateral growth of the maxillary arch and lateral lingual pressure exerted during swallowing.

The low level resting pressures over a long period of time that occur within the oral cavity are technically difficult to measure. However, the high levels of pressure of short duration that occur during swallowing and speaking are comparatively easy to determine. The relationship of these "functional" pressures to oral cavity size will determine if their inclusion in a function-form theory is required. Therefore, the purpose of this study was to determine if a correlation occurs between the lingual pressure exerted against the maxillary arch during speech and swallow and the size of the oral cavity.

## Method

Nine children were selected as subjects for this study from a larger population involved in a longitudinal investigation of lingual pressures and dental occlusion. The subjects were selected who provided a wide range of oral cavity sizes as determined by measurements previously described by Brown and McGlone (*2*). From cephalograms of each child made with teeth in occlusion, the following measurements, as illustrated in Figure 1, were obtained:

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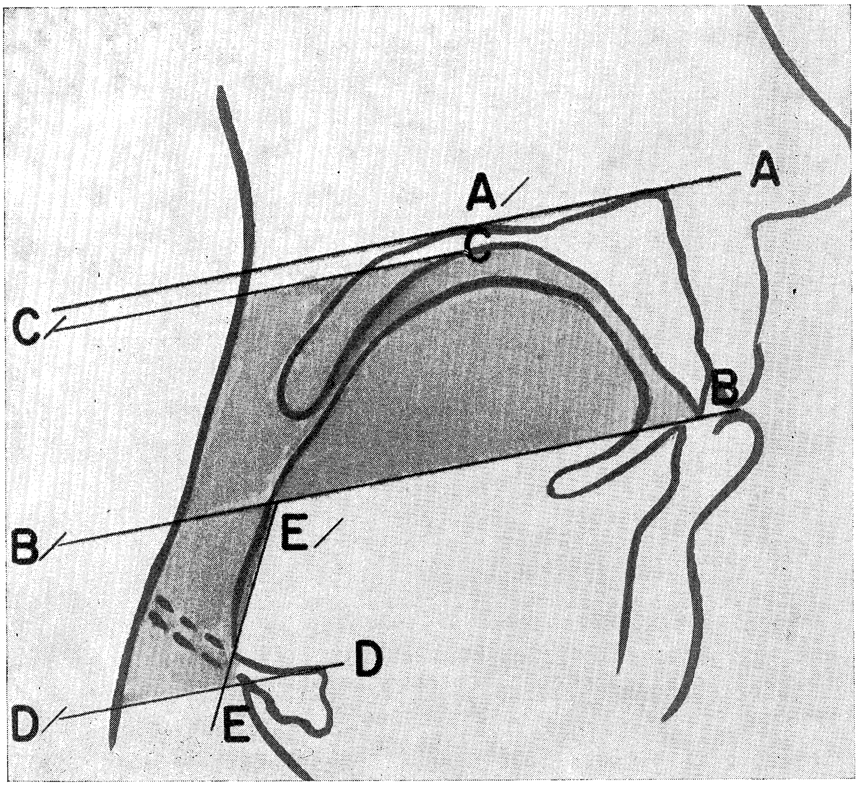


FIGURE 1. An illustration of the boundaries of the oral cavity.

A line, A–A′, was drawn on the x-ray through the most anterior point of the nasal spine of the maxilla and the point where the superior surface of the palate meets the zygomatic process of maxilla. This line was used as the reference line for the other borders of the oral cavity.

For the superior border, a line was drawn from the tip of the central incisors B, following the curvature of the incisors, alveolar ridge and bony palate to the most superior aspect of the palatal arch, C. From here a line (C–C′) parallel to A–A′ was drawn through the posterior pharyngeal wall.

The posterior pharyngeal wall was used as the posterior border of the vocal tract. For the inferior border a line (D–D′) was drawn from the most superior point of the body of the hyoid bone parallel to A–A′ to intersect the posterior pharyngeal wall.

A line (B–B′) drawn from B parallel to the reference line A–A′, served as the inferior border of the oral cavity.

As for the anterior border from the point on line D–D′ where that line transects the anterior pharyngeal wall, a line was erected to intersect with B–B′.

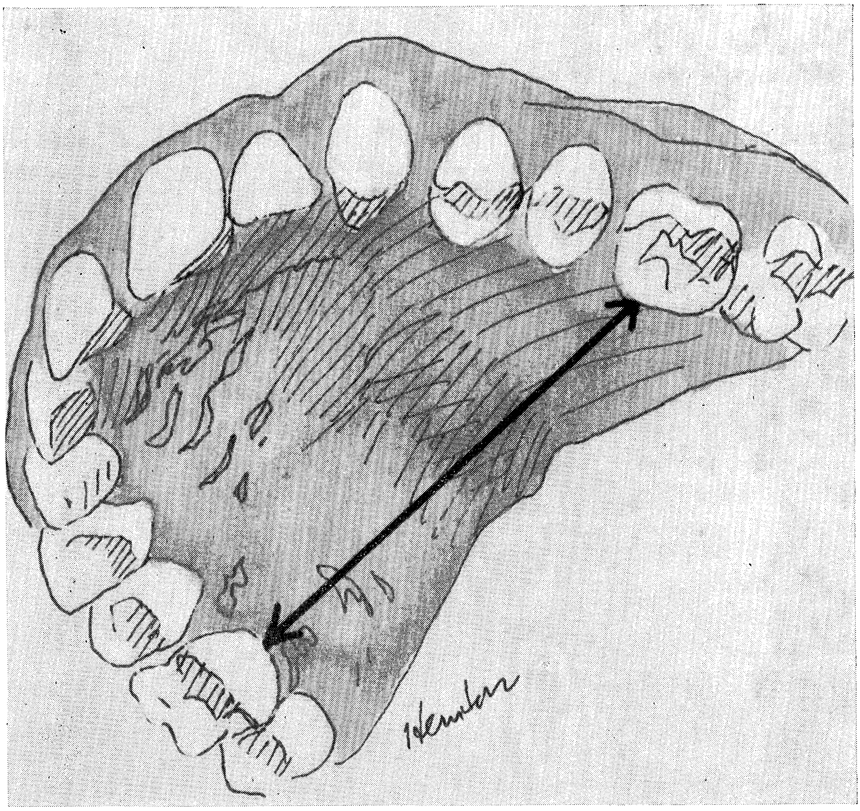

FIGURE 2. An illustration of the width measurement made from an impression of the maxillary arch.

This area enclosed from B to C to, and along, the posterior pharyngeal wall to E to E′ and back to B indicated by the dark area on the figure, was measured with the aid of a planimeter.

Figure 2 illustrates the measurement made from dental impressions of maxillary arch. The width between the extreme medial aspects of the first upper molars was measured from the dental cast of each subject. Using the area measurement from the cephalogram multiplied by the molar width obtained from the dental cast an estimate of the size of the vocal tract was made. The range of cavity sizes obtained in the selection process was 45.5 cc to 78.1 cc. The largest size was smaller than the smallest adult measurement reported by Brown and McGlone.

This measurement is acknowledged to be a static measurement of a channel which changes in both size and shape during speech production and swallowing. However, since subjects repeated the same activities, tract size variations would generally be the same for each subject.

Additional criteria for subject selection were that all children have essentially normal oral and dental structures and normal speech.

Lingual pressures against the alveolar ridge were obtained by the use of resistance strain gage transducers. The strain gages were mounted on a beam which bent in response to pressure, distorting the strain gage and altering its electrical resistance. The change in resistance was measured. This change was analogous to the pressure. These gages were quite strain-sensitive, and with modern design to control artifacts, were also quite stable and accurate (*6*).

An IBM digital computer facilitated the kind of data processing needed for this project. Analog signals were generated by pressure transducers and analog-to-digital conversion was carried out by the computer. Calibration and data acquisition occurred on-line, and included immediate a-to-d conversion, after which the digitized data were stored on magnetic tape. Recovery included all calculations, and could be done at any time after acquisition. The system for recording pressure measurements is described in detail elsewhere (*8*).

Lingual pressures were measured at three points within the oral cavity. The left and right transducers were in the area of the first premolars, the center transducer was mounted along the median raphe directly behind the central incisors.

Each subject was asked to repeat the consonants /t/, /d/, and /n/, and the vowels /i/, and /o/ combined into consonant-vowel, vowel-consonant-vowel, and vowel-consonant syllables. Each combination was repeated three times each. The consonants represented voiceless, voiced and nasal consonants and the vowels represented a high front and low tongue position during their production. Swallows were obtained by having the child sip water and swallow it.

## Results

Two lingual pressure measures were obtained from the speaking and swallowing activities. These measures were the pressure peak and the area under the pressure curve. Fifty-four syllable utterances were averaged for each speaker to obtain representative scores of his speech pressures. Ten swallows from each subject were averaged to obtain the swallowing values.

Relationships of the measures of interest were determined by calculating their rank order correlations which are presented in Table 1. As seen in this table, low correlations were obtained for both measures, although higher results occurred for swallow than for speech.

A further illustration of this lack of correlation is present in Table 2. In this table the measures for each subject are given for the center location using the time-pressure area measures. From inspection of these numbers it can be seen that the least amount of pressure over time was exerted by subject 7 for both swallow and speech while the highest value was found for swallow from subject 9 and from subject 4 for speech.

The over-all means of these measures again illustrate the difference in

TABLE 1. Rank order correlations of oral cavity size with the area under the tongue pressure curves (pressure-time integral) and peak tongue pressures during swallow and speech.

| | *left* | *center* | *right* |
|---|---|---|---|
| | Pressure-time Integral | | |
| Swallow | .33 | .47 | .28 |
| | Peak | | |
| | .38 | .27 | .40 |
| | Pressure-time Integral | | |
| Speech | .27 | .07 | .07 |
| | Peak | | |
| | .25 | .04 | .13 |

pressure magnitudes between swallowing and speech reported previously by Proffit, McGlone and Christiansen (*4*). Peak swallow pressures were at least three times as great as peak pressures during speech at all three transducer locations. Integrated pressure-time measures during swallow exceeded speech by at least eight times.

## Discussion

The results of this study suggest that there is little relationship between the size of the oral cavity and the pressures exerted against it by the tongue during either speech utterances or swallow. This further confirms the findings of Proffit, Chastain and Norton, who used only measurements of lateral maxillary arch growth compared to lateral lingual pressure

TABLE 2. Mean pressure-time integral values (in gm-sec./cm$^2$) for both swallow and speech arranged in order of increase in subject oral cavity size (in cc).

| *subjects* | *cavity size* | *swallow* | *speech* |
|---|---|---|---|
| 1 | 45.5 | 86.0 | 17.6 |
| 2 | 55.9 | 86.9 | 13.1 |
| 3 | 56.1 | 121.7 | 2.5 |
| 4 | 62.8 | 355.8 | 56.8 |
| 5 | 63.4 | 164.9 | 5.6 |
| 6 | 66.9 | 134.4 | 13.6 |
| 7 | 67.2 | 81.7 | 1.9 |
| 8 | 76.5 | 150.4 | 9.8 |
| 9 | 78.1 | 706.4 | 28.5 |

during swallowing. Apparently during both speech and swallow the tongue makes only as much contact with the teeth and alveolar ridge as necessary to perform the required activity. For speech, tongue contact is essential for sealing the oral cavity to permit the air pressure build up necessary for producing several speech sounds. For swallow, the tongue, in addition to closing the mouth area to impound food also forces the food toward the pharnyx and esophagus. The higher correlations between cavity size and swallow are probably related more to the larger area of contact necessary in this act than to any function-form relationship.

The lack of correlation may be interpreted to mean that carrying out of these functions is essentially lingual. That is to say, the neural control of the muscles of the tongue govern the force and, hence pressure, that it exerts for each of these activities, and that control is dictated by the requirements necessary to complete the act. This view contrasts with that of the tongue as being thrust upward and forward in an essentially uncontrolled manner (*3*). If this latter view were correct, a high correlation, either positive or negative, should have occurred.

The data from this study contribute additional support to the concept that intense forces of short duration are less related to form-function relationships than the longer but smaller resting forces. Although any correlation technique cannot determine the cause or effect of an activity, it seems reasonable that if dynamic lingual pressures did contribute significantly to arch form, the tongue would closely fit the arch during these acts. Perhaps the true situation in the oral cavity is a "semi-functional" matrix, where functional activities contribute to the overall growth, but to a limited extent.

**Summary**

Nine children with oral cavities that represented a wide range of sizes were selected as subjects. Tongue pressures against the maxillary arch were measured during speech and swallowing. The correlations between these oral activities and cavity size were small. These results suggest that functional activities contribute only to a limited extent to the overall growth of the oral cavity.

**References**

1. Brader, A., Dental arch form in relation to intra-oral forces, *Angle Orthodontist* (in press).
2. Brown, W. and McGlone, R., Relation of intra-oral air pressure to oral cavity size, *Folia Phoniat., 21,* 321–331 (1969).
3. Malecot, A., Mechanical pressure as an index of force of articulation, *Phoneticas, 14,* 169–180 (1966).
4. Proffit, W., McGlone, R., and Christiansen, R., Lingual Pressures against anterior and lateral areas of the palate during speech and swallow. Paper presented at International Association for Dental Research, Toronto, 1965.
5. Moss, M., and Salentijn, L., The primary role of functional matrices in facial growth, *Amer. J. Orthodont. 55,* 154–166 (1969).

6. Paterson, R., Proffit, W. and McGlone, R. Developments in transducers for studying linguo-palatal contacts, *J. Acoust. Soc. Amer. 42,* 1209 (1967)A.
7. Proffit, W. and Norton, L., The tongue and oral morphology: Influences of tongue activity during speech and swallowing, *ASHA Report, 5,* 106–115 (1970).
8. Proffit, W., Chastain, B., and Norton, L., Linguo-palatal pressures in children, *Amer. J. Orthodont., 55,* 566–577 (1969).
9. Tully, W., A critical appraisal of tongue thrusting, *Amer. J. Orthodont., 55,* 640–649 (1969).