Anterior Open Bite and Oral Port Constriction

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Despite numerous studies by speech and dental investigators the cause and effect relationship between malocclusion and speech performance remains unclear. The anterior open-bite malocclusion is one possible exception. There is some evidence that the frequency of certain consonant and vowel distortions increases in the presence of this deformity.[4,6,7,9,10,12,18] Harrington and Breinholt[6] relate the central protrusion lisp to anterior open-bite malocclusion and question whether continued misarticulation may have further adverse effects upon the dental arches and teeth. Bernstein[12] also noted lisping in patients with anterior open bite but reported that the severity of the speech defect did not directly relate to the degree of open bite or the extent of overjet or overbite. It appears that some individuals with open bite can properly produce sibilant sounds by compensatory adjustment of the lower lip in relation to the air stream thereby developing the required air turbulence.[1]

The fricative consonants, /s/, /z/, /ð/ (voiced th), /θ/ (voiceless th), /f/ and /v/ are most affected by an open bite.[4,10]

In a recent investigation by Munim,[18] seventeen patients with anterior open-bite malocclusion and eight patients with normal occlusion were evaluated clinically, cephalometrically and phonetically to determine if any correlation exists between the deformity and defective speech. Munim observed a tongue-thrust swallow pattern in fourteen of the seventeen open-bite subjects. The tongue's anterior-posterior rest position did not differ between the two groups but there was an excessive forward positioning of the tongue during /s/ sound production in the open-bite group. There was a high incidence of sound distortions among open-bite subjects and the consonants /s/, /ʃ/, /z/, /l/, and /r/ were affected in that order. He found only two subjects with near normal speech production. The cephalometric study showed that the maxillomandibular plane angle was excessively larger in the open-bite group. This may force the tongue to be lower in the mouth and might contribute to sound distortions by interfering with normal movement. Munim also found less depression of the mandible during /s/ production in the open-bite sample which may be an attempt to control a larger than normal air passage. This might confine the tongue somewhat and cause defective /s/ sounds. The fact that anterior open bite is a vertical discrepancy and does not call for an extra translatory movement of the mandible during speech was supported by the cephalometric analysis. The analysis also demonstrated that the tip of the tongue moved farther forward during /s/ sound production in the open-bite group.

In recent years aerodynamic techniques have been refined allowing more precise study of certain speech parameters. Two such parameters, intraoral pressure and airflow, have been measured during normal speech production.[14-20] By direct measurement of transportal air pressure and rate of oral airflow during speech, another parameter, the area of oral port constriction,

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may be calculated.[15] This constriction is needed to create turbulence as the airflow passes through the vocal tract which, in turn, results in the noise source that forms acoustic excitation in the air-filled cavities that are anterior and posterior to the constriction.[21]

Warren and Ryon[22] define oral port size as the degree of oral constriction resulting from placement of the tongue against the teeth, palate, alveolar ridge, or lips during fricative sound production. Hixon[15] investigated simultaneous variations in transportal air pressure, oral airflow rate, and the area of maximum oral constriction associated with specified conditions of turbulent noise production for speech. Voiceless fricative articulation was studied on nine normal speaking young adult males. The instrumentation was similar to that used by Warren and DuBois[23] to calculate velopharyngeal orifice area during continuous speech. From the recordings of intraoral air pressure and oral airflow rate the area of maximum oral constriction was computed utilizing an equation similar to that reported by Warren and DuBois.[23]

The purpose of the present investigation was to compare the values of oral port constriction during fricative sound productions in open-bite subjects with the values obtained in subjects with normal occlusion and speech. Differences between subjects with normal and open-bite occlusions were compared in terms of degree of dental anomaly and articulatory proficiency.

Materials and Methods

Two groups of subjects were utilized in this study. The first consisted of ten subjects, three male and seven female. The age range was nine to thirty-one years. All subjects in group one demonstrated both normal speech and normal occlusion. The second group consisted of ten subjects, six male and four female with the same age range as group one. All subjects were examined in the graduate orthodontic clinic of the University of North Carolina School of Dentistry. Each subject in the second group had an anterior open-bite malocclusion.

A comprehensive history which included habits, allergies, mouth-breathing, presence of tonsils and adenoids, and any previous speech therapy was taken on all subjects in both groups. A complete clinical examination was performed on all and, in addition, plaster models were constructed for the open-bite group. From this information the occlusion was classified and the amount of open bite measured. All the control subjects had Class I normal occlusions and no subjects in the open-bite group were selected if missing, spaced or severely rotated teeth or severe overjet were present. The open bite was measured in millimeters vertically between the anterior teeth from the upper central incisors to the lower central incisors (Fig. 1). The speech of each subject was evaluated by a speech pathologist. This evaluation specifically disclosed the incidence of fricative errors during connected speech.

Oral masks were made in assorted sizes from self-curing rubber and modified to fit firmly over the upper lip, against the cheeks, and above the chin. Two small plastic catheters, approxi-

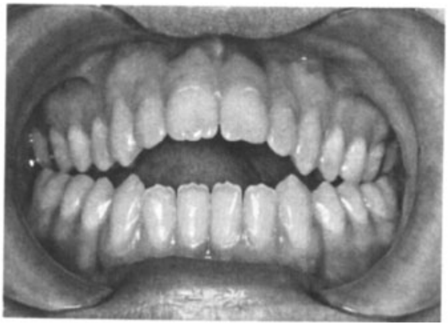

Fig. 1 The open bite was measured vertically between the upper and lower central incisors.

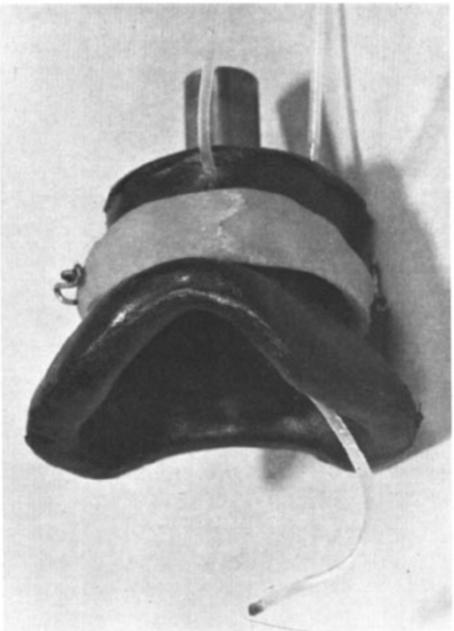

Fig. 2 The mask used to measure rate of oral airflow and air pressure during speech.

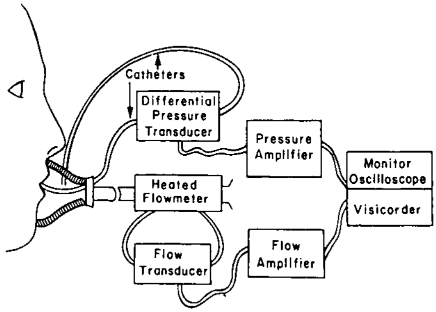

Fig. 3 Diagrammatic representation of the equipment used.

mately 40 cm in length with an internal diameter of 1.5 mm, were placed through each mask, one through the superior and one through the posterior surface (Fig. 2).

The patient was seated at the instrument table with the mask positioned to assure contact only at the facial perimeter with pressure adequate to prevent air leakage but not great enough to distort the speech sounds. A plastic tube with one centimeter internal diameter connected the mask to a pneumotachograph (Fig. 3) which consisted of a heated flowmeter and a transducer. One catheter from the superior surface of the mask was connected to the low side of a pressure transducer. The other catheter passed through the posterior surface of the mask and was connected to the high side of the pressure transducer. The free end of this catheter extended into the mouth to record oropharyngeal pressure. This free end was occluded with wax and, medial to the occlusion, two small holes approximately one millimeter in diameter were placed on opposite sides of the catheter wall. This method allowed measurement of the static pressure in the oropharynx and greatly reduced the chances of recording spurious, dynamic pressures. The use of dual catheters in this manner enables one to measure the pressure differential, Δ p, between the oropharynx and the external oral area. Therefore, the resistance produced by the apparatus (mask, tubing, etc.) through which the air column must pass after leaving the mouth is not reflected in the recording.

The oropharyngeal catheter was molded to conform to the subject's maxillary buccal segment high in the vestibule and curved around the upper last molar (Fig. 4). This placed the end of the catheter in the midpalatal area about 4-5 mm down from the palate itself directly in the oral air stream. The subjects were cautioned not to bite or occlude the catheter with the tongue. If the subjects did occlude the catheter, it was readily apparent on the monitor oscilloscope and the recording.

Each subject was instructed to repeat a series of test phrases before the mask was placed. They were told to speak at a normal conversational level and normal utterance rate in order to maintain a constant speech intensity

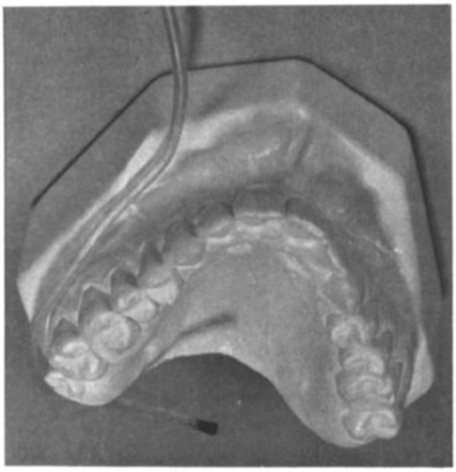

Fig. 4 Placement of the oropharyngeal catheter on the dental model.

and speed. The mask was then placed in position and the subjects again repeated the test phrases. The voiced and voiceless fricative sounds /s/, /z/, /f/, and /v/ were used. Each sound was produced in isolation and in the carrier phrase "say __at again." Each test item was repeated four times. Therefore, each subject made a total of 32 sound productions which usually required approximately 20 minutes.

The changes that occurred in transportal air pressure and rate of oral airflow during the speech sounds were simultaneously recorded by a direct writing instrument on photosensitive paper. Upon completion of each session the pressure and flow were calibrated at a pressure of two centimeters of water and a flow rate of 250 cubic centimeters of air per second.

The area of oral constriction was calculated from the parameters of pressure and airflow using a modified hydraulic equation:

$$\text{Area of oral port constriction (cm}^2\text{)} = \frac{\text{Airflow Through Oral Port (cm}^3\text{/sec)}}{k\sqrt{\dfrac{2\,[\text{Transportal Pressure}]\ (\text{dynes/cm}^2)}{\text{Density of Air (gm/cm}^3\text{)}}}}$$

The equation is based upon a modification of the Theoretical Hydraulic Principle which was reported by Warren and DuBois[23] for measuring the area of the velopharyngeal orifice. It was applied to the calculation of the area of maximum oral constriction by Hixon.[15] Although Hixon did not include the correction coefficient (k), originally reported by Warren and DuBois, it was used in this study to obtain approximation of the actual area rather than the theoretical area. The constant takes into consideration the turbulent, nonuniform and rotational characteristics of the airflow. The calculated k value used was 0.65.

Measurement of transportal air pressure of the fricatives /s/, /z/, /f/ and /v/ was made at the peak amplitude of the recorded deflection as illustrated at point A of Figure 5. The oral airflow rate was measured at the point of maximum pressure deflection by a perpendicular from this peak through the flow record which is the same point in time (point B, Fig. 5). The area of oral constriction was calculated from these values using the equation previously discussed. For each sound studied, the four repetitions were averaged and a mean value recorded.

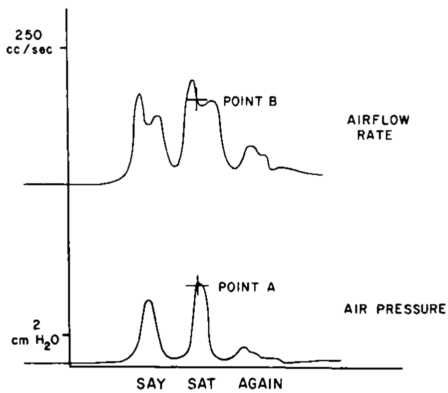

Fig. 5 Measurement of pressure was made at point A and airflow at point B.

TABLE I

AREA OF ORAL PORT CONSTRICTION IN CONTROL SUBJECTS (MM^2)

	Fricative sounds produced							
Subject	/s/	sat	/z/	zat	/f/	fat	/v/	vat
1	4.0	2.6	4.8	3.6	10.7	2.3	3.6	1.4
2	3.2	1.0	4.5	1.8	3.1	1.0	5.8	1.5
3	7.5	6.9	6.4	5.4	2.9	1.2	0.6	0.4
4	2.1	1.9	5.0	1.0	2.4	0.1	1.4	0.4
5	4.7	0.8	3.4	1.2	8.4	4.6	3.9	1.7
6	7.9	5.7	7.7	6.5	6.5	0.8	4.4	0.5
7	10.3	1.4	7.7	4.6	14.7	2.6	4.3	2.7
8	8.8	4.3	7.6	6.7	10.4	4.8	7.9	5.2
9	6.4	3.3	3.7	2.6	9.0	1.3	6.6	2.5
10	10.0	4.1	4.6	3.5	2.4	1.5	4.6	4.0
Mean	6.49	3.20	5.54	3.69	7.05	2.02	4.31	2.03
S.D.	2.88	2.05	1.67	2.08	4.28	1.58	2.20	1.60
S.E.	0.91	0.65	0.54	0.66	1.35	0.50	0.69	0.51

Results

Comparison of the Area of Oral Port Constriction Between Control and Open-Bite Subjects. For the control group, the mean oral port area for each subject and for each sound produced is reported in Table I. In addition, the mean, standard deviation and standard error are reported for each sound. The same data are presented for the open-bite group in Table II. The open-bite subjects are listed in order by the degree of vertical open bite in millimeters, the most severe being first. The corresponding subject in the control group is matched for age.

The oral port area means were compared between the two groups for each sound as shown in Table III. An F test was performed to determine the significance of the true variances. On the basis of the F test, the appropriate t-test was used to test the means. The results show significantly larger oral port constriction areas for open-bite subjects compared with control subjects for every sound.

Open-Bite Group Means. Analysis of the data revealed differences in oral port area values when the amount of open bite approached 5 mm. Therefore, the open-bite group was divided into

TABLE II

AREA OF ORAL PORT CONSTRICTION IN OPEN-BITE SUBJECTS (MM^2)

	Fricative sounds produced								Amount of open bite
Subject	/s/	sat	/z/	zat	/f/	fat	/v/	vat	(mm)
1	14.1	24.4	6.3	16.8	24.5	45.9	13.4	17.6	8
2	13.8	20.4	10.4	14.1	13.8	16.6	13.5	15.7	7
3	14.3	9.1	12.1	8.3	16.3	7.8	9.2	9.4	6
4	25.9	12.5	10.1	10.1	24.1	8.5	12.9	14.0	6
5	11.6	4.5	10.6	3.6	10.6	5.1	8.3	9.6	4
6	8.0	9.1	8.8	8.7	12.6	2.5	8.9	4.2	4
7	5.4	4.6	10.1	9.4	8.7	7.5	8.3	10.9	3
8	10.8	5.3	6.3	6.3	9.6	4.2	13.7	5.5	3
9	8.7	6.3	8.9	9.3	12.7	4.3	5.5	4.8	3
10	10.3	2.9	10.4	1.7	3.8	11.2	15.3	6.1	3
Mean	12.29	9.91	9.40	8.83	13.67	11.36	10.90	9.78	
S.D.	5.58	7.22	1.87	4.45	6.53	12.80	3.23	4.75	
S.E.	1.77	2.28	0.59	1.36	2.06	4.05	1.02	1.50	

TABLE III
COMPARISON OF THE AREA OF ORAL PORT CONSTRICTION BETWEEN CONTROL AND OPEN-BITE SUBJECTS

Fricative Produced	t-value	Sig. Level
/s/	2.92	0.5%
sat	2.83	1.0%
/z/	4.87	0.5%
zat	3.31	0.5%
/f/	2.68	1.0%
fat	2.29	5.0%
/v/	5.34	0.5%
vat	4.89	0.5%

$t_{.95} = 1.73$
$t_{.99} = 2.55$
$t_{.995} = 2.88$

severe (5 mm and above) and moderate (below 5 mm). Means and standard deviations were calculated for each sound for both groups. The mean oral port areas for each sound in the severe open-bite group were compared with the mean for each sound in both the moderate open-bite group and the control group. The mean oral port area value for each sound in the moderate group was then compared with each mean value for the control group. Analysis of the variance was performed for all sounds and the t-test applied.

The severe open-bite group produced significantly larger oral port areas than did the moderate open-bite group. Five of the eight sounds studied showed significant differences between the means (Table IV). The severe open-bite group also showed significantly larger oral port area values when compared with the control group. Only the /f/ in "fat" showed no significant difference (Table V). In addition, the subjects with moderate open bite were compared with the control subjects (Table VI). The oral port constriction areas were significantly larger in the moderate open bites for six of the eight sounds. Only the /z/ in "zat" and /f/ in isolation showed no significant difference.

TABLE IV
AREA OF ORAL PORT CONSTRICTION OF SEVERE OPEN BITE COMPARED WITH MODERATE OPEN BITES (MM^2)

Fricative	Open bite	Mean	S.D.	t-value	Sig. Level
/s/	Severe	17.03	5.92	2.55	5.0%
	Moderate	9.13	2.26		
sat	Severe	16.60	7.03	3.08	5.0%
	Moderate	5.45	2.11		
/z/	Severe	9.73	2.45	0.43	ns
	Moderate	9.18	1.60		
zat	Severe	12.33	3.84	2.60	5.0%
	Moderate	6.50	3.24		
/f/	Severe	19.68	5.44	3.67	0.5%
	Moderate	9.67	3.29		
fat	Severe	19.70	17.92	1.53	ns
	Moderate	5.80	3.11		
/v/	Severe	12.25	2.05	1.09	ns
	Moderate	10.00	3.72		
vat	Severe	14.18	3.51	3.63	0.5%
	Moderate	6.85	2.87		

ns = not significant

TABLE V

AREA OF ORAL PORT CONSTRICTION OF SEVERE OPEN BITES COMPARED WITH CONTROL SUBJECTS (MM^2)

Fricative	Open bite	Mean	S.D.	t-value	Sig. Level
/s/	Severe	17.03	5.92	3.40	5.0%
	Normal	6.49	2.88		
sat	Severe	16.60	7.03	3.75	5.0%
	Normal	3.20	2.05		
/z/	Severe	9.73	2.45	3.74	0.5%
	Normal	5.54	1.67		
zat	Severe	12.33	3.84	5.55	0.5%
	Normal	3.69	2.08		
/f/	Severe	19.68	5.44	4.64	0.5%
	Normal	7.05	4.28		
fat	Severe	19.70	17.92	1.97	ns
	Normal	2.02	1.58		
/v/	Severe	12.25	2.05	6.20	0.5%
	Normal	4.31	2.20		
vat	Severe	14.18	3.51	6.65	0.5%
	Normal	2.03	1.60		

ns = not significant

TABLE VI

AREA OF ORAL PORT CONSTRICTION OF MODERATE OPEN BITES COMPARED WITH CONTROL SUBJECTS (MM^2)

Fricative	Open bite	Mean	S.D.	t-value	Sig. Level
/s/	Moderate	9.13	2.26	1.91	5.0%
	Normal	6.49	2.88		
sat	Moderate	5.45	2.11	2.10	5.0%
	Normal	3.20	2.05		
/z/	Moderate	9.18	1.60	4.29	0.5%
	Normal	5.54	1.67		
zat	Moderate	6.50	3.24	1.26	ns
	Normal	3.69	2.08		
/f/	Moderate	9.67	3.29	1.29	ns
	Normal	7.05	4.28		
fat	Moderate	5.80	3.11	2.77	5.0%
	Normal	2.02	1.58		
/v/	Moderate	10.00	3.72	3.88	0.5%
	Normal	4.31	2.20		
vat	Moderate	6.85	2.87	4.36	0.5%
	Normal	2.03	1.60		

ns = not significant

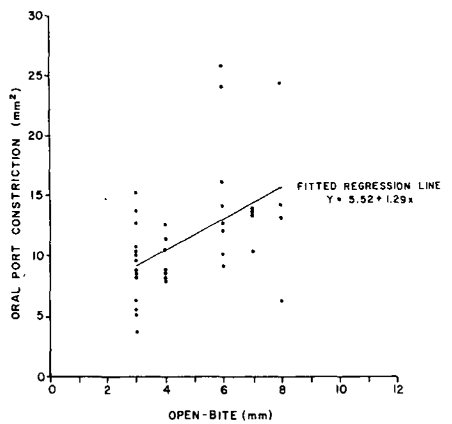

Fig. 6 The relationship between open bite and oral port area for isolated fricative sounds.

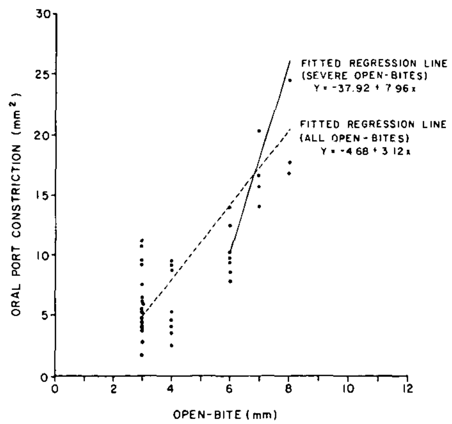

Fig. 7 The relationship between open bite and oral port area for fricative sounds in a carrier phrase.

Degree of Open Bite and Oral Port Constriction. The amount of open bite for each subject is listed in Table II and ranged from 3 to 8 mm. The amount of open bite for each subject was compared graphically in Figure 6 with the oral port constriction area for each sound produced in isolation. A linear regression line was fitted for the values and is shown in Figure 6. The regression coefficient was calculated and a t-test showed the coefficient to be significant at the 0.5% level. A correlation coefficient of 0.78 was calculated and found to be significant at the 0.5% level. These results are reported in Table VII and indicate that oral port area in production of sounds in isolation increases as the degree of open bite increases.

The fitted linear regression line for the sounds produced in carrier phrases is shown in Figure 7. The regression coefficient was found to be significant at the 0.5% level and the correlation coefficient was 0.88 and significant at the 0.5% level. Both are reported in Table VII and indicate that, for sounds placed in carrier phrases, the area of oral port constriction also increases as the degree of open bite increases.

In addition, a fitted linear regression line for the carrier phrase sounds of only the severe open bites is shown in Figure 7. The regression coefficient and the correlation coefficient of 0.98 both were found to be significant at the 1% level as shown in Table VII. This indicates a very close relationship between oral port area and open bite in

TABLE VII
DEGREE OF OPEN BITE RELATED TO AREA OF ORAL PORT CONSTRICTION

Fricatives	Regression Coefficient b	t-value Regression	Sig. Level	Correlation Coefficient r	t-value Correlation	Sig. Level
Isolated	1.29	3.58	0.5%	.78	3.58	0.5%
Phrase	3.12	5.18	0.5%	.88	5.18	0.5%
Phrase Open bite Only	7.96	8.43	1.0%	.98	8.43	1.0%

TABLE VIII

DEGREE OF OPEN BITE AND ARTICULATION ERRORS

Subject	Degree of Open bite (mm)	Articulation Errors /s/	/z/	/f/	/v/	Total
1	8	11	13	4	3	31
2	7	0	0	0	0	0
3	6	10	8	3	2	23
4	6	7	6	0	0	13
5	4	10	6	0	0	16
6	4	6	11	0	0	17
7	3	11	8	0	0	19
8	3	9	6	2	2	19
9	3	11	10	0	0	21
10	3	8	2	0	0	10
Errors Possible =		11	15	9	9	43

cases with 5 mm or greater open bite.

Articulation Errors. Table VIII shows the number of articulation errors out of a possible 43 fricative sounds evaluated for each open bite subject. The mean number of errors was 17 for the open-bite group and 0 for the control group. Errors were observed by a speech pathologist during connected speech. Most of the articulation errors occurred on the fricatives /s/ and /z/ and very few for /f/ and /v/. Although statistical analysis showed no significant correlation between the number of articulation errors and either the degree of open bite or the oral port area, it is important to note that the most severe open-bite subjects also had the greater number of speech errors (except subject No. 2).

Discussion

The areas of oral port opening for control subjects producing /s/ and /f/ in isolation (Table I) closely approximated the values reported by Hixon.[15] The mean for /s/ in the present study was 6.49 mm^2 compared with Hixon's 6.94 mm^2 and the mean for /f/ in the present study was 7.05 compared with his 9.91 mm^2. Our area values are also similar to those reported by Claypoole[24] for normal subjects.

The open-bite group produced significantly larger values of oral port area than control subjects for every fricative sound studied (Table III). Even with the teeth in occlusion, subjects with anterior open bite could not approximate the incisal edges of their upper and lower anterior teeth as required for production of /s/ and /z/. The open-bite subjects also encountered some difficulty in bringing the lower lip up to the incisal edge of the upper teeth for proper /f/ and /v/ sound production. Both of these anatomical relationships provide the narrow air pathway needed for adequate fricative sound production.

The data reported in Table V demonstrate that subjects with the more severe anterior open bite (5 mm and over) had larger oral port area values than the control group. The subjects with moderate open bite (below 5 mm) also showed significantly larger oral port constriction than the controls (Table VI). As the open bite increased over 5 mm, the oral port values became significantly larger. It appears that many of the moderate open-bite subjects are able to produce almost normal oral port areas by compensating with their tongues. Many of the subjects used a more forward tongue placement which narrowed the oral port airway and produced more accurate sounds. However, in general, the more severe open-bite subjects were unable to compensate adequately for the open bite and produced larger oral port areas.

In addition, there was a direct correlation between the amount of open bite and the area of oral port constriction for isolated fricatives as well as fricatives placed in carrier phrases (Figs. 6 and 7). For the carrier phrase sounds the correlation was even higher in the more severe open bites (Fig. 7).

Certain fricative sounds, especially /s/ and /z/, were more difficult for some of the severe open-bite subjects to produce and this was reflected in a greater number of articulation errors (Table VIII). This is in contrast to Bernstein's[12] observation that the severity of the speech defect does not vary directly with the amount of open bite, as well as Rathbone's[18] similar observation. In addition, since oral port areas increased as the amount of open bite increased, it appears that the open-bite defect is often associated with inadequate speech production. This is in partial disagreement with Ingervall and Sarnas[8] who suggest that the open bite is not responsible for defective speech. They attribute the defective speech to a low and protruded tongue position. This tongue position, however, may be due to an attempt to compensate for the open bite and, therefore, the open bite is most likely the direct cause of the speech problem. This type of compensation was reported in Jensen's[25] study of Class II, Division 1 subjects. He found that acceptable fricative speech was achieved by tongue placement anterior to the lower incisors and/or the lower lip was placed against the incisal edge of the upper incisors.

A greater number of articulation errors was noted in some of the most severe open-bite subjects but some of the less severe open-bite subjects also demonstrated a large number of speech errors (Table VIII).

More articulation errors were observed for /s/ and /z/ than for /f/ and /v/, even though oral port areas were generally larger for all sounds. This may reflect the fact that the open-bite subjects were able to compensate better for /f/ and /v/ or that /f/ and /v/ can be produced with greater variations of oral port size. Since the incisal edges of the upper and lower teeth cannot be approximated, only tongue position may be modified to produce an acceptable /s/ and /z/ sound. For /f/ and /v/ the lower lip in addition to the tongue may be used to some advantage in producing the proper sounds.

Summary

Intraoral air pressure and rate of oral airflow were measured simultaneously during fricative sound production in ten subjects with anterior open bite and ten subjects with normal occlusion and speech. From these measurements the area of oral port constriction was calculated and the values compared within and between the two groups.

Findings revealed that:

(1) The area of oral port constriction was very consistent and reproducible in subjects with normal speech production and normal occlusion.

(2) The area of oral port constriction was significantly larger in open-bite subjects compared with control subjects for all sounds.

(3) Severe anterior open-bite subjects with a vertical defect over five millimeters were found to produce significantly larger oral port openings than those with only moderate open bite (3-5 mm) for most sounds.

(4) A direct correlation between the degree of open bite and the area of oral port constriction was found. As the

amount of open bite increased, the area of the oral port increased, especially in the severe open-bite group (5 mm and over).

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