Relation Between Speech Production and Oro-facial Structures in Individuals with Isolated Clefts of the Palate

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Most investigators agree that some relation exists between the adequacy of speech articulation and variations in the dentition. The acceptance of such a relation does not necessarily imply cause and effect since many individuals with severe malocclusions can have adequate speech articulation while others with good occlusion have less than adequate speech articulation skills. The presence of an oral cleft and its subsequent management adds a series of variables which renders the relationship between articulation and the orofacial structures much more difficult to study.

Thus, the purpose of this investigation was to compare orofacial structures and speech phonemes in subjects with isolated clefts of the palate who exhibited various degrees of velopharyngeal competency and articulatory proficiency; and to correlate the various orofacial measurements with sound production.

Literature review

McDermott (*3*) examined 54 individuals with repaired palatal clefts in order to explore the factors which effect /s/ sound production. Judgments were made of the presence and degree of deviation in the anterio-posterior relationships of the dental arches, the continuity of the cutting edge of the anterior teeth, the general configuration of the hard palate and the mobility of the tongue. He found significant differences in articulation adequacy of the /s/ sound between subjects with severe deviations and subjects with the slight and moderate deviations. McDermott's results suggest that the combination of deviations of various aspects of dental structures mitigate against correct /s/ sound production.

Subtelny and Subtelny (*6*) examined 27 adult cleft palate individuals. They obtained cephalometric laminagraphs and tape recordings of a nonsense-syllable articulation test. The laminagraphs were traced and analyzed to quantitate velopharyngeal and dental relationships. Tape recordings were played back to a panel of listeners for phonetic transcriptions. Their findings indicate that the total number of articulatory errors was not found to be consistently or

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significantly related to measurements made between upper and lower incisors. They pointed to the fact that the five patients with the highest number of articulatory errors and the five cases with the lowest number of errors both had an anterior incisor relation which ranged between 3.0 mm of overjet and −5.0 of anterior crossbite.

Starr (*5*) felt that although articulation is a learned behavior in both the cleft and normal groups, it is still affected by environmental and psychological factors as well as organic deviations. He also suspects that cleft and noncleft groups differ systematically on several important nonorganic factors. He further stated that in the organic area it is evident that similar dental conditions occur in patients with or without clefts. Starr advocated further research employing techniques for either investigating one variable while holding others constant, or for looking at interactions between variables.

This brief literature review points to the need of a better understanding of the influence of the different dentofacial parameters on speech production. The position of the upper and lower incisors were traditionally thought to be the most important variable which might affect the production of certain sounds; e.g., labiodental. On the other hand one can also assume that the size and relation of the maxilla and mandible to each other and to the rest of the craniofacial complex could influence the size of the oral cavity proper as well as the relation of the palate to the posterior pharyngeal wall. Such variations of anatomical structures might influence the functions and relations of the tongue as well as that of the soft palate.

Therefore it seems necessary that an attempt should be made to relate the speech sounds to different dentofacial parameters in order to have a better understanding of any existing correlations between these two parameters.

Materials and methods

Sample: In this study 72 individuals with isolated clefts of the palate were examined. On each individual, a lateral cephalogram as well as scores for the Danish Articulation test were available.

All 72 individuals were females, all were Caucasian (Danish), all were operated using the same palatoplasty (Wardill 3 or 4-flap procedure), all were operated by the same surgeon and finally, all records were taken using standardized procedures. The description of the sample is detailed in Table 1.

The 99 Item Articulation Test used for Danish subjects had been previously described by Van Demark (*7*). In this test, which was administered in Danish, the items included consonants spoken as singletons, blends and triple-ton clusters. As constructed, the test contained 152 elements including those items found in the Danish Pressure Articulation Test. This test is comparable to other articulation tests used in Denmark and has normative data for 4, 6, and 7-year-old subjects.

The phonemes /b/, /p/, /m/ (bilabial), /v/, /f/ (labiodental), /d/, /t/, /s/, /n/, /1/ (alveolar), /r/, /j/ (palatal), and /k/, /g/ (velar) were tested four times and were used in the correlation analysis. It was also possible to calculate a percent correct for each phoneme.

TABLE 1. Descriptive data on the sample used in this investigation.

	Total Group (N=72)	Closure (N=37)	Marginal (N=25)	Non-Closure (N=10)*
Age at Observation in years	12.0 ± 4.7	11.1 ± 4.1	12.4±4.7	13.3 ± 5.0
Age at Surgery in years	2.1 ± 1.1	2.1 ± 0.7	2.2±1.0	2.0 ± 2.1
Cleft Width in mm	9.7 ± 4.3	9.7 ± 4.1	10.6±3.5	7.4 ± 6.6
Cleft Type:**1	6 (8%)	2 (5%)	1 (4%)	3 (30%)
2	16 (22%)	11 (30%)	4 (16%)	1 (10%)
3	38 (53%)	20 (54%)	16 (64%)	2 (20%)
4	12 (17%)	4 (11%)	4 (16%)	4 (40%)
Dental Classification				
No malocclusion	20 (28%)	11 (30%)	5 (20%)	4 (40%)
Class I	32 (45%)	18 (49%)	11 (44%)	3 (30%)
Class II	14 (19%)	5 (13%)	7 (28%)	2 (20%)
Class III	6 (8%)	3 (8%)	2 (8%)	1 (10%)
Ortho. Treatment	8 (11%)	3 (8%)	5 (20%)	None

* 3 individuals in the non-closure subgroup had obturators postsurgically.

**Cleft type 1: Bifid uvula or incomplete cleft of the soft palate.

Cleft type 2: Complete cleft of the soft palate.

Cleft type 3: Cleft of the soft palate and imcomplete cleft of the hard palate.

Cleft type 4: Complete cleft of the soft and hard palate extending to the incisive papilla.

Individuals were also rated clinically, regarding their velopharyngeal competence into: closure, marginal and non-closure (incompetence). The assessment of velopharyngeal closure was made on the basis of a composite diagnostic evaluation-taking into consideration a subject's conversational speech, word articulation test, manometer ratios oral examination and lateral x-rays on phonation of /s/ or /u/ (*8*).

For the purpose of this study the total cleft group was divided into 3 subgroups according to this clinical rating. Positive and negative manometer (with bleed) were also available.

The following descriptive information was also recorded for each patient; age of observation, age of palatoplasty, cleft width (as measured before surgery), the dental classification of occlusion (according to Angle's), overbite and overjet.

Lateral cephalograms were taken with the head oriented to Frankfort Horizontal Plane and with the teeth in occlusion. The following landmarks were identified (Figure 1) and pricked using a sharp needle, on each cephalogram: Sella (S), Nasion (N), Subspinale (A), Anterior Nasal Spine (Ans), Supramental (B), Pogonion (Pog), Gnathion (Gn), Menton (Me), Gonion (Go), Postgonion

(Postp), Long axis of maxillary incisor ($\underline{1}$), Long axis of mandibular incisor ($\overline{1}$). Perpendicular from Ans on N-Me line (Ans′) and pterygomaxillary fissure (Ptm). The definitions of these landmarks were described in detail elsewhere (*2, 4*). Two reference planes were constructed namely the anterior cranial base plane from Nasion to Sella (N:S) and the mandibular plane (MP) from Menton to Gonion.

The following angles were measured: SNA and SNAns relating the maxilla to the anterior cranial base; SNB, SNPog, NSGn, MP:SN relating the mandible to the anterior cranial base; ANB and NAPog relating the maxilla and mandible to each other as well as to the anterior cranial base; and finally $\overline{1}$:MP, $\underline{1}$:SN and $\underline{1}$:$\overline{1}$ to evaluate the anteroposterior position of the incisor teeth.

The following linear measures were also recorded from the cephalograms: upper face height (N:Ans′); total face height (N:Me), maxillary depth (Ans-Ptm); mandibular depth (Pog:Pospt); anterior cranial base (S:N), overbite, which is the vertical distance the maxillary incisors overlap the mandibular incisors (in millimeters) and overjet which is the horizontal distance between the incisal edge of the most anterior maxillary incisor and the labial surface of the most anterior mandibular incisor (in millimeters).

Five different ratios were calculated N-ANs′/N-Me, Ans-Ptm/S-N, S-N/N-Me, N-Ans′/S-N and Ans-Ptm/Pog-Postp.

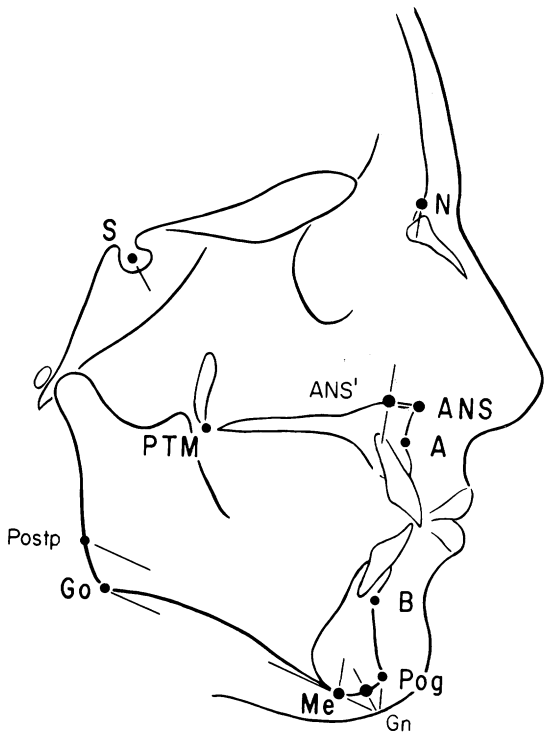

FIGURE 1. Landmarks used to construct the different cephalometric measurements.

Two sets of measurements were obtained by two investigators independently. Inter- and intra-examiner relatability were calculated and were found to be within acceptable limits. The methods of determining the reliability were described in detail elsewhere (*1*).

Statistical methods used: The sample was divided according to the clinical rating of velopharyngeal competence into: closure, marginal and non-closure. Means ($\bar{x}$) and standard deviations (S.D.) were calculated for both the cephalometric measurements and the percent correct for each speech sound. F-statistics were used to compare the three subgroups. Correlations (r) between the different dentofacial measures and percent correct articulation scores for each sound were computed. In addition, multiple or stepwise regression (R) were calculated. In these analyses the percentages of correct articulation of each speech sound was the dependent variable and the dentofacial parameters examined served as independent variables.

Results

F-statistics comparing 24 dental and facial parameters failed to demonstrate statistically significant differences ($p \geq .05$) for any of the parameters studied as a function of closure category.

As would be expected, those manner of production categories which do not require as much intra-oral pressure (nasal and glides) did not show differences in percent correct for any of the three groups. Pressure phonemes (fricatives and plosives) were significantly different at the .001 level of confidence. Thus as velopharyngeal competency decreases the percent of correct production of pressure sounds also decreases.

It is of interest to observe in Table 1 that the non-closure subgroup exhibited greater variability in age at the time of palatoplasty as well as cleft width. In addition, the velopharyngeal incompetence (non-closure) subgroup had the highest percentage of individuals with bifid uvula (less severe cleft) and a relatively lower incidence of malocclusion.

A total of 1,344 *correlation coefficients* (r) between the percentage correct for different speech phonemes and the angular and linear measurements for the total group and each of the three subgroups were calculated and are presented in Tables 2 and 3. In reporting the data in these tables we have attempted to look at groups of phonemes related to either their place of production; i.e., bilabial, labiodental, etc. or the degree of velopharyngeal competency.

Table 2 includes correlations relating angular measurements to different phonemes. Although statistically significant correlations were present we could not establish any consistent trends between dentofacial relations and phonemes grouped either according to place or manner of articulation. It is interesting to note that the maxillary and mandibular incisor angulations had very few correlations with the different phonemes.

Table 3 includes correlations relating the linear dentofacial measurements and phonemes. Although many dentofacial measures demonstrate a significant *r* with different phonemes, those measures which are significant with one sound are not

TABLE 2. Correlation data between the angular cephalometric parameters and the speech phonemes.

Sound \ Groups	Total	Closure	Marginal	Non-Closure
p		SNAns*		
b		SNA*	-NAPog*	
m	-ANB*, $\underline{1}$: SN*			
v		$\overline{1}$: MP*	-ANB*,-NAPog*	
f			-MP : SN*	
d				
t		SNB*,SNPog*, $\overline{1}$:MP*		-SNA*'
s			SNB*,SNPog*, -NSGn*, $\underline{1}$:SN	
n				$\underline{1}$: SN*'
l	-NSGn*,-MP :SN*	SNA*,SNAns*,-NSGn*		
r	SNB*,SNPog*,-ANB, -NAPog*, $\underline{1}$: SN*	SNAns*	-ANB**',-NAPog**'	$\underline{1}$:SN*'
j			1 : MP*	-NAPog*', $\underline{1}$: SN**'
g		SNA**,SNAns**',SNB*, SNPog*, $\overline{1}$: MP**	-MP:SN*, $\underline{1}$:SN*	
k			-NSGn*,-MP:SN*	

* $p \leq .05$

** $p \leq .01$

' signifies an r value of 0.5 or greater.
negative correlations have a "-" designation.

consistently significant with the other related (according to the place or manner of articulation) sounds. For example, in production of bilabial phonemes, if one considers place of articulation, one would expect all measures that are significant to production of /b/ to also be related to production of /p/ and /m/. On the other hand if manner of articulation is important one would expect the same variables related to /p/ to be also significant with /b/. When Table 3 is examined in this manner, it appears that very few trends are evident.

When the same correlations in Table 3 are examined according to velopharyngeal competency groups, we find that the phonemes in the closure subgroup are most frequently related to face height, overbite, maxillary depth and mandibular depth. In the marginal subgroup the most common correlation is a relationship between anterior cranial base and sound production, yet for those phonemes which do not require intra-oral pressure a relationship does not exist. For the non-closure subgroup, most phonemes demonstrate a negative relationship with cleft width, the exception again being those sounds which do not require velopharyngeal closure.

Regarding the incidence of malocclusion (Table 1), the non-closure subgroup has the highest percentage of individuals with normal occlusion (40%); on the other hand, the marginal subgroup has the highest percentage of individuals with malocclusion (80%).

STEPWISE REGRESSION STATISTICS: The results of the multiple regression analysis points to the fact that there are many significant correlations yet, there are great variations which are present in the regression equations of the different phonemes examined in this investigation.

ARTICULATION SCORES AND FACIAL PARAMETERS: Since the findings in this investigation indicated that there are no statistically significant differences in the dentofacial parameters between the closure, marginal and incompetent subgroups, an attempt was made to explore whether CPO individuals with above average and below average articulation scores show significant differences in these parameters.

Those individuals with the highest articulation score; i.e., above 139.8 ($\bar{x}$ + 1 S.D.) and those individuals with the lowest scores; i.e., below 80.6 ($\bar{x}$ − 1 S.D.) were compared. The first subgroup consisted of 13 subjects while the latter subgroup consisted of 14 subjects. For each of these two subgroups means and standard deviations were calculated and comparisons were performed between the two subgroups. No significant differences were found between any of the parameters examined except for the articulation scores which is to be expected.

It was noted that there was an increase of approximately 1.5 times in the incidence of malocclusion in the subgroup with low articulation scores. Yet when the x^2 − test was used to compare the two groups, no significant differences were found ($p \geq .05$). It was also noted that the subgroup with high articulation scores included a higher percentage of individuals with more severe clefts.

Discussion

An attempt was made in this investigation to relate the adequacy of production of various speech sounds to different dentofacial parameters in individuals with

TABLE 3. Correlation data between the linear cephalometric parameters and the speech phonemes.

Sounds \ Groups	Total	Closure	Marginal	Non-Closure
p	N:Ans**,S:N**,pog:postp*, N:Ans/N-Me*	N:Ans*,N:Me*,Ans:Ptm*,overbite*	N:Ans*,S:N**'	N:Ans**',N:Me*'
b	N:Ans*,S:N*	N:Ans**,N:Me*,Ans:Ptm*,overbite*, N:Ans/N-Me*	S:N**', N:Ans/N:Me*	-width**'
m	-Ans:Ptm/pog:postp*			
v	N:Ans**,S:N**,N:Ans/N:Me**	N:Ans**,N:Ans/N:Me**',overbite*		-width**'
f	-Ans:Ptm/S:N*		S:N*'	-width*'
d	N:Ans*,S:N*	N:Ans**,N:Me*	S:N**'	-width**',S:N*'
t	N:Ans**,S:N**,pog:postp*, N:Ans/N:Me*	N:Ans**,Ans:Ptm**,pog:postp*, N:Ans/N:Me*,overbite*	S:N*	-width*'
s	N:Ans**,S:N**,pog:postp*, N:Ans/N:Me*	N:Ans**,Ans:Ptm*,pog:postp*, N:Ans/N:Me**,overbite*	S:N**'	-width*'
n	N:Ans*,N:Me*,S:N*,pog:postp**, overbite**	overbite*		Ans:Ptm**',S:N*'
l	S:N*,overbite**	S:N*,overbite**		
r	N:Me*,S:N*,pog:postp**, -Ans:Ptm/pog:postp*	pog:postp*,overbite**		Ans:Ptm**',S:N*'
j	N:Ans*,N:Ans/N:Me*			Ans:Ptm**',S:N*', pog:postp*'
g	N:Ans**,N:Me*,S:N**,pog:postp*	N:Ans**',N:Me*,Ans:Ptm**',S:N*, pog:postp**,Ans:Ptm/N:Me*,l:l*,overbite**'	N:Ans*,S:N**'	-width*',N:Ans*' N:Me*'
k	N:Ans*,S:N**	N:Ans**,N:Me,Ans:Ptm**,S:N*, pog:postp*,overbite*	S:N*	-width*',N:Ans**', N:Me*',S:N*'

* $p \leq .05$
** $p \leq .01$
' signifies an r value of 0.5 or greater.
negative correlations have a "-" disignation.

operated clefts of the palate. Both correlation coefficients and multiple regressions indicated that there are many significant relationships between the degree of production adequacy of some speech sounds and different dentofacial structures. Such correlations were generally low and did not demonstrate a uniform relationship for all phonemes in a particular place of articulation such as bilabials. Furthermore, the relationships did not follow a pattern when various degrees of velopharyngeal closure were considered.

The present findings on individuals with isolated clefts of the palate as well as the previous results reported in the literature on both cleft and non-cleft individuals tend to indicate that subjects with good or poor articulation do not differ systematically in their facial and dental relations.

One might then hypothesize that of the different causes which lead to inadequate articulation, anatomical variations may play a minor role in this process. However, in the absence of gross anatomic deviations, it is possible that different parameters can interact together to influence articulation. These interactions are for all practical purposes neither well defined nor readily detectable with the methods used in either this or previous investigations. Other parameters than the one used may provide more conclusive relationships.

Summary

Although many significant but low concentrations were present between different speech phonemes and some of the dentofacial parameters examined in this investigation, one is unable to demonstrate any consistent trends which can be clinically useful to either the orthodontist or speech pathologist.

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References

1. BISHARA, S. E., Effects of Wardill-Kilner (V/W-Y) Palatoplasty on Facial Growth. *Angle Ortho. 45,* 55–65, 1975.
2. KROGMAN, W. M., and V. SASSOUNI, *Syllabus in Roentgenographic Cephalometry* (Mimeographed) Philadelphia, 1957.
3. MCDERMOTT, R. P., A Study of /s/ Sound Production by Individuals with Cleft Palates. University of Iowa Ph.D. Thesis, 1962.
4. MEREDITH, H. V., Serial Study of Change in a Mandibular Dimension During Childhood and Adolescence. *Growth 25,* 229–242, 1961.
5. STARR, C. D., Dental and Occlusal Hazards to Normal Speech Production. Chapter 43 in W. C. Grabb, S. W. Rosenstein, and K. R. Bzoch (eds.), *Cleft Lip and Palate: Surgical, Dental and Speech Aspects,* 373–392, (Little, Brown and Company, Boston, 1971).
6. SUBTELNY, J. D., and J. D. SUBTELNY, Intelligibility and Associated Physiological Factors of Cleft Palate Speakers. *J. Speech Hear Dis. 2,* 353, 1959.
7. VANDEMARK, D. R., K. JORGENSEN, and A. A. VANDEMARK, Acquisition of Articulation Skills for Normal Danish Children. Accepted for Publication, *Tale og Stemme.*
8. VANDEMARK, D. R., A Comparison of Articulation Abilities and Velopharyngeal Competency Between Danish and Iowa Children with Cleft Palate. *Cleft Pal. J. 11,* 463–470, 1974.