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Recently, there has been renewed interest in the impact of oral-facial myofunctional factors on dentofacial development and orthodontic retention. While it has long been debated whether muscle function influences bone formation and morphology, advances[1] in scientific methods have recently allowed empirical examination of this issue. Experimental and clinical evidence suggest that dental and skeletal relationships can be significantly influenced by changes in the local environment.[2] For example, treatments for Class II malocclusions which attempt to modify jaw and tooth position through altering lower jaw growth[3-5] illustrate the growing recognition of the importance of environmental variables in orthodontic intervention.

McLoughlin[6] and Hanson[7] reviewed the current and historical information on myofunctional factors such as negative oral habits, mouthbreathing, lingual rest and swallow patterns and other behaviors which have been shown to have an effect on dentition and facial growth. The environmental factor most widely viewed as influential in the development of dentofacial anomalies is the open-mouth posture associated with mouthbreathing. Chronic mouthbreathers are frequently characterized by an open-mouth posture, a nose that appears to be flattened, nostrils that are small and poorly developed, a short upper lip, and a fuller lower lip. These individuals can display retroclined incisors, a narrow v-shaped upper jaw with a high narrow palatal vault, a Class II skeletal relationship[8-9] or a posterior cross-bite, and a tendency for open bite.[10] It is argued that these morphological adaptations are a result of an alteration in activity of specific facial muscles related to mouthbreathing.

Prevention of dentofacial growth problems and orthodontic retention issues remain particularly controversial.[11-15] Gottlieb[16] recommended more study and attention to the role of muscles and airway in the cause and course of treatment of malocclusion and the stability of correction.

Hale, Kellum and Bishop[15] reviewed the records of 229 patients in a private orthodontic

Abstract

One hundred and thirty-three second graders in rural public school were assessed on a number of dental, skeletal, and oral muscle function measures. Correlational analyses were conducted in order to determine whether specific myofunctional variables were associated with dentofacial development. Significant relationships were observed between open mouth posture and a narrow maxillary arch and long facial height. Labial and lingual rest and swallow patterns were also related to poor coordination of lip and tongue movements.

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Key Words

Dentofacial development • Myofunctional

Table I
Race and gender composition of the sample.

Gender	Race							
	Black		White		Other		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
Male	35	(52.2)	25	(42.4)	5	(71.4)	65	(48.9)
Female	32	(47.8)	34	(57.6)	2	(28.6)	68	(51.1)

Note: Total N = 133. Percentage represents column percent.

practice regarding the prevalence of myofunctional factors and behaviors. These youngsters displayed a high frequency of open mouth posture (68.6%), as well as low tongue posture during swallow (73.3%), speech (48.0%), and at rest (71.6%). Moreover, patient and parental reports revealed that 45.6% of the children in the sample engaged in negative oral habits (e.g., thumbsucking, nail biting, lip licking, etc.). A National Health Survey[17] conducted by the U.S. Department of Health, Education and Welfare also indicated that negative oral habits such as thumb- and finger-sucking were associated with malocclusion.

The data presented by Hale et al.[15] suggest that myofunctional variables may play an important role in dentofacial development. However, because the observations were conducted on a sample of children exhibiting dentofacial anomalies, conclusions regarding this relationship are limited. A better understanding of myofunctional factors and dentofacial development should result from examinations of the relationships among these variables in the general population.

The purpose of the present investigation was to further examine the relationships among dentofacial anomalies and myofunctional behaviors. Children in a public school setting were measured on a number of dental, skeletal, and myofunctional factors. Analyses were performed in order to determine whether the presence of specific oral-muscle habits and behaviors was associated with increased dentofacial problems.

Materials and methods

Subjects

One hundred and thirty-three second-grade children attending a public school in a rural community served as subjects. The average age of the children was 8.4 years (SD = 5.5 months). Sixty-eight of the subjects were females and 65 were males. A gender by race summary is contained in Table I.

Measures

Molar relationships were determined by an orthodontist using the criteria established by Angle's Classification system.[18] Molar relationships were assessed by examining the area where the mesial labial cusp tip of the maxillary first molar met the developmental groove between the mesial and middle labial cusp of the mandibular first molar.

Overjet was measured by placing a millimeter gauge against the mesial portion of the mandibular right central incisor at the gingival border. While the patient was biting in the comfortable centric occlusion position, the distance to the mesial incisal edge of the maxillary right central incisor was measured at the facial surface.

Overbite was determined utilizing the same reference points used to measure overjet. The amount of enamel visible at the mandibular right central incisor between the mesial incisal edge of the maxillary central incisor and the gingival margin of the mandibular central incisor at the mesial portion was measured using a millimeter gauge (boley gauge).

Maxillary arch width was determined by placing a millimeter boley gauge against the lingual groove at the gingival border of the maxillary first molar. The distance to the same place on the opposite maxillary first molar was then measured.

Measurement of skeletal facial morphology included soft tissue measures of facial height, lower face height, and facial width.[19] Total facial height was determined by placing a large millimeter boley gauge against the soft tissue points located at the nasion (junction of the frontal and nasal bone) and the menton (most inferior point on the chin) and reading the distance between these reference sites. Lower facial height was obtained by placing the boley gauge at the point just below the nose at the labial nasal angle and the most inferior point on the chin (menton) and measuring the distance between these points. Facial width was assessed by using the spreading calipers to determine the distance between the most lateral point on one zygomatic arch and the other zygomatic arch.

Oral muscle control (diadochokinesis) was assessed using the Fletcher method[20] in which the subject was asked to produce a series of speech syllables in rapid succession. Speed of production was timed for each of three different types of syllables: single, bi-, and tri-. The single syllable assesses rapid repetitive movement of the lips. The bi- and tri-syllable involved coordination of lip and tongue movements.

Open mouth posture was assessed during a

Table II
Descriptive statistics for the dentofacial measures for the total sample and by gender.

	Gender					
	Male		Female		Total	
	M	SD	M	SD	M	SD
Variables						
Maxillary arch width	34.30	3.60	33.20	3.17	33.74	3.42
Overjet	3.35	1.69	3.28	1.73	3.32	1.70
Overbite	3.22	1.67	3.03	1.76	3.12	1.71
Total facial height	104.14	6.86	102.87	6.86	103.63	6.86
Lower facial height	55.88	5.33	54.86	8.38	55.37	7.11
Facial width	112.26	7.81	110.97	6.77	111.60	7.30
Dental occlusion	%		%		%	
Class I	60.0		55.9		57.5	
Class II	30.8		39.7		35.1	
Class III	4.6		4.4		4.5	

Note: Occlusal data represent column percentages. May not total 100% due to missing data. Total N = 133. All measurements are in millimeters.

quiet listening activity which consisted of the subjects watching a nature film. During the five-minute viewing session, children were observed and recorded as having open or closed mouth posture in three time intervals of 1½ minutes each. If subjects had two out of three open ratings, they were defined as open mouth posture.

Acoustic and placement aspects of the speech sounds /l, t, d, n, s, z/, which are typically lingua-alveolar, were observed. The child's productions of the sounds were scored as sounding acoustically correct or incorrect on a sentence imitation task. The place of articulation or lingual touch point was determined from observation of articulation in a single word picture stimulus task. The touch point for the target sounds was noted as lingua-alveolar, upper lingua-dental, interdental, or lower lingua-dental.

The examiners analyzed various anatomical and physiological aspects of the facial and oral mechanisms to determine if any potentially negative or at risk variables were present. The observations included evaluation of the upper and lower lip lengths, shape and competence of the upper lip at rest and mobility of the lips during speech and swallow, observations of nasal and oral breathing activities, tongue tip touch points for rest and swallow, lingual and labio frenum restriction, and negative oral habits.

Procedures

The assessment procedures were divided into three components with different teams obtaining the measurements for each component. Occlusion and maxillary arch width were assessed by an orthodontist who conducted a dental examination on each subject. The children remained in their classrooms and were evaluated individually by the orthodontic team. The children watched while their classmates were assessed for this and the other measurements.

A team of doctoral students in psychology under the supervision of a clinical psychologist with extensive experience in behavioral inter-

Table III
Myofunctional descriptive statistics for the total sample and by gender.

	Male	Female	Total
	%	%	%
Variables			
Resting mouth posture			
Closed	60.0	69.1	64.2
Opened	38.5	30.9	34.3
At-rest tongue posture			
Lingua-alveolar	30.8	42.6	36.6
Dentalized	69.2	57.4	62.7
Articulation placements			
Lingua-alveolar	15.4	13.2	14.2
Dentalized	83.1	86.8	84.3
Swallowing patterns			
Lingua-alveolar	53.8	61.8	57.5
Dentalized	46.2	38.2	41.8
Oral habits			
Thumb-sucking			
Absent	76.9	77.9	76.9
Present	23.1	20.6	21.6
Nail-biting			
Absent	41.5	35.3	38.1
Present	58.5	63.2	60.4

Note: Percents represent column percent of total sample (N = 133). May not total 100% due to missing data.

vention in orthodontic management obtained the measures of total and lower facial height and facial width. These measurements were obtained on each subject in the classroom.

The diadochokinetic, open-mouth posture, articulatory placement, labial and lingual rest and swallowing postures, and oral habit measurements were obtained by master's degree students in speech/language pathology. These observers were supervised by two certified speech/language pathologists with extensive experience in craniofacial and myofunctional disorders. Each child was observed by an examiner for open mouth posture while watching a TV monitor with a group of four other children. Each subject was then individually evaluated for diadochokinesis and myofunctional variables. These measures were completed in the child's classroom or in an adjacent room.

Reliability

Reliability of measurement for the myofunctional variables and open mouth postures was conducted on 20% of all evaluations (in each category). A second observer independently performed these measures on randomly selected subjects. Reliability was calculated by dividing the number of agreements by the total number of observations. Reliability ranged from 71% to 100% with a mean of 87%.

Reliability was also calculated for the soft tissue measures of total facial height, lower facial height, and facial width. A second observer independently performed these measures on 20% of the sample. Reliability coefficients were computed using Pearson product moment correlations. The analysis revealed significant correlations between observers on these measures (facial height, $r = .74$, $p < .001$; lower facial height, $r = .54$, $p < .004$; facial width, $r = .89$, $p < .001$).

Results

Total sample descriptive statistics for the dentofacial measures (i.e. maxillary arch width, overjet, overbite, total facial height, lower facial height, facial width and occlusal patterns) are presented in Table II. Table III includes the descriptive statistics for the myofunctional measures (i.e. mouth posture, rest, speech, swallow, tongue postures and oral habits of thumb-sucking and nail-biting. The diadochokinetic rates are presented in Table IV.

Gender and racial differences in these dentofacial and myofunctional measures were assessed with independent-samples *t* tests (continuous data) and Pearson chi-square analyses (categorical data). No gender differences were found on any measure. Racial differences were found for maxillary arch width, $t(124) = 4.2$, $p < .001$ (black $\underline{M} = 32.38$, $SD = 3.18$; white $\underline{M} = 32.38$, $SD = 3.12$), facial height, $t(124) = 3.59$, $p < .001$, (black $\underline{M} = 103.75$, $SD = 7.0$; white $\underline{M} = 99.50$, $SD = 5.84$), lower facial height, $t(124) = 4.96$, $p < .001$, (black $\underline{M} = 58.17$, $SD = 8.13$; white $\underline{M} = 52.32$, $SD = 4.32$), and facial width, $t(124) = 5.16$, $p < .001$, (black $\underline{M} = 113.76$, $SD = 7.48$, white $\underline{M} = 107.92$, $SD = 4.74$).

The relationships between open mouth posture and myofunctional and dentofacial measures were analyzed with Pearson product moment correlation coefficients (for the continuous data) and Chi-square contingency tests (for the categorical data). In particular, open mouth posture was correlated with the following variables: maxillary arch width, facial height, lower facial height, facial width, overjet, overbite, diadochokinetics, and articulatory placement variables. (Alpha was set at .01 in order to reduce the likelihood of a Type I error.)

Table IV
Diadochokinetic rate for males, females, and total sample (N = 133).

	Male		Female		Total	
	M	SD	M	SD	M	SD
Diadochokinetic rate						
Single syllable	4.96	1.26	4.64	.89	4.79	1.09
Bi-syllable	6.29	1.63	6.48	1.63	6.39	1.39
Tri-syllable	6.69	1.17	6.33	1.14	6.50	1.16

Using the total sample, open mouth posture was correlated with a more narrow maxillary arch width, $r(130) = .18$, $p = .04$. In addition, open mouth posture was related to longer facial height, $r(130) = .23$, $p = .01$. Open mouth posture was also correlated with a slower single syllable diadochokinetic rate, $r(120) = .29$, $p = .002$. No other significant correlations were observed.

The diadochokinetic rate measures for the entire sample were further analyzed by examining the relationship between extreme scores ($z > .75$ or $z < .75$ in single syllable, bi-syllable, tri-syllable, and other myofunctional variables). Chi-square contingency analysis revealed that a slow tri-syllable diadochokinetic rate was related to a dentalized resting tongue posture, Chi-square $(1) = 7.7$, $p = .006$, and a dentalized swallow pattern, Chi-square $(1) = 3.8$, $p = .05$.

In order to examine further the potential influence of the racial differences observed for some of the facial measures, the relationships between open mouth posture and the myofunctional measures were re-analyzed by race. These analyses were also conducted by gender. Fisher's z tests were computed to determine significant ($p < .05$) differences in the correlations by race or gender. No correlations were found to differ significantly by race or gender.

Discussion

Children in second grade classrooms in a public school setting were assessed for a number of dental, skeletal, and oral muscle factors. Data analyses revealed that open mouth posture was associated with a narrow maxillary arch width and longer facial height. Additionally, slower oral muscle movements were related to labial and lingual rest and swallow postures.

The relationship observed between open mouth posture and narrow maxillary arch width and longer facial height has been previously reported by other investigators.[8-9] In children exhibiting appropriate closed mouth posture the position of the tongue at rest is in a retroflexed position with alveolar contact. Youngsters displaying open mouth posture maintain the tongue in a forward plane. The exertion of tongue forces on the hard palate may play an influential role in the development of the maxillary arch.

Upper and lower lip mobility and muscle tone, as reflected in the single syllable diadochokinetic rate measures, were also related to open mouth posture. This relationship may be a result of different muscle activity requirements associated with open mouth versus lip seal postures. When compared to lip seal, maintaining an open mouth posture may require a lesser degree of muscle activity. Greater muscle tone and coordination would be expected to result from more demanding muscular regimens.

Poor coordination of lip and tongue movement, as reflected in slow rates of tri-syllable diadochokinetic productions, was associated with dentalized tongue resting and swallowing postures. Inactive muscle states might contribute to reduced labial and lingual competence, producing poor oral muscle coordination. Surprisingly, unlike the single syllable diadochokinetic measure of muscle function, tri-syllable rates were not related to open mouth posture.

A number of anticipated relationships between oral muscle factors and dentofacial development were not observed. For example, open mouth posture was not associated with a specific occlusal pattern, nor were labial and lingual rest and swallow patterns related to particular molar relationships. While this may be interpreted as evidence that many of the oral muscle factors studied do not influence dentofacial development, a number of issues must be addressed before considering this conclusion.

A high incidence of suspected negative oral muscle factors was observed in this sample. Currently, there are no frequency norms regarding how these factors are distributed across the general and orthodontic populations. Without these data it is not possible to determine whether these variable show developmental characteristics. It is feasible that many of these behaviors are a necessary step in the development of appropriate oral muscle function. Significant adverse dentofacial effects may only be found when an individual deviates from the norm and fails to grow out of a particular behavior pattern. Only longitudinal research will be able to successfully address this issue.

Although few significant relationships between oral muscle factors and dentofacial development were identified, open mouth posture was associated with a narrow maxillary arch and longer facial height. This finding raises questions concerning the importance of correcting these inappropriate oral muscle behaviors during orthodontic intervention. If a narrow maxillary arch and long facial height is in part a result of inappropriate exertion of lingual forces in a low forward plane, redirecting these pressures to the appropriate structures would possibly enhance treatment response. That is, such behavior change would eliminate one potential source of resistance to the corrective forces exerted by fixed appliances.

Retention of orthodontic treatment effects is often noted as a significant problem.[21] It is typically assumed that relapse is due to poor follow-up treatment compliance. That is, youngsters fail to continue to wear their retainers as instructed. However, if muscular forces of the tongue, for example, are significant variables in dentofacial development, once fixed appliances are removed these natural muscular forces acting on the teeth would no longer be opposed. As a consequence relapse may ensue. In light of the data presented, this hypothesis must be considered speculative. However, since youngsters typically have their braces removed during their early to mid teens while they are still growing, it seems important that a better understanding of the influence of oral muscle structures and function be obtained.

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