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Developmental Effects of Impaired Breathing in the Face of the Growing Child

Craniofacial morphology and occlusal pattern are evaluated in 71 subjects having impaired breathing as diagnosed by an otolaryngologist, and in an equal number of controls. The impaired group demonstrate characteristic combinations of craniofacial deformities and malocclusions, with the younger individuals demonstrating a lesser expression of malocclusion progression and morphologic deformities. This suggests that early recognition of such facial patterns may be utilized to identify those breathing compromised individuals who have a likely tendency to develop certain types of malocclusion.

KEY WORDS: · BREATHING · NASAL OBSTRUCTION · CRANIOFACIAL DEFORMITIES · MALOCCLUSION ·

Impaired breathing is known to represent a significant factor contributing to the underlying etiology of dentofacial deformities during childhood growth. However, the results of several clinical studies (HUBER AND REYNOLDS 1946; LEECH 1958; WATSON ET AL. 1968; LINDER-ARONSON 1970) indicate that the craniofacial relationships associated with mouth breathing are variable, and can be associated with differing facial patterns. Experimental studies using primates carried out by Harvold and associates (HARVOLD ET AL. 1973 AND 1981; HARVOLD 1975 AND 1979) also showed varied dentofacial forms and malocclusions resulting after the establishment of mouth breathing.

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The variety of skeletal and dental configurations observed in animal experiments and human mouth breathers have been presumed to be secondary results of neuromuscular adjustments required to maintain adequate respiratory function (Miller and Vargervik 1979; McNamara 1981; Shaughnessy 1983).

Individual neuromuscular activities have been reported to have close relationships with facial pattern. Tallgren (1970) found greatest alveolar bone resorption in those wearers of complete dentures who had a rectangular facial shape and larger mandibular curvature with a small gonial angle. Ingervall and Thilander (1974) reported that brachyfacial persons, having a large mandibular curvature and a small gonial angle, tend to show a more anteriorly oriented and biomechanically more efficient muscular pattern than dolichofacial persons.

Based on clinical observation, Bench, et al. 1977 pointed out that facial types having stronger musculature are characterized by a brachyfacial form with deep bite and a low mandibular plane. Those with a high mandibular plane angle, dominantly vertical pattern, open bite, and dolichofacial characteristics have a weaker musculature and are less able to overcome the adverse effects of orthodontic treatment forces that tend to open the bite and rotate the mandible.

Because these different facial patterns show varying neuromuscular activities, the lack of consistency in malocclusion types among subjects with impaired breathing might relate to their varied intrinsic facial patterns.

Facial patterns tend to show a close association with specific combinations of composite regional anatomic "counterparts." Enlow (1982) qualitatively described the human face as the aggregate sum of all the many balanced and unbalanced craniofacial parts combined into a composite whole. A specific facial pattern has close association with a specific headform, basicranial flexure, nasomaxillary length, palate shape, ramus inclination and relative bony arch size (Enlow 1982; Bhat and Enlow 1985).

Using both lateral and P-A cephalographs, evaluation of morphologic combinations may thus provide more information about facial patterns than observation of single linear or angular values. There is still inadequate quantitative information on transverse anatomic relationships for subjects with nasal obstruction.

The purpose of the present study is to clarify anatomic and functional interrelationships associated with impaired breathing, varied neuromuscular activities, and facial pattern variations. The following two objectives are specifically addressed:

1. To determine whether characteristic combinations of morphologic and occlusal features characterize those individuals who develop facial dysplasia as compared with controls.
2. To test a hypothesis that specific types of malocclusions found in subjects with nasal obstruction relate to certain intrinsic morphologic combinations.

— Materials and Methods —

The breathing-impaired sample comprised 41 male and 30 female subjects, 15 of whom were Black and 56 Caucasian. The age range was 3.8 to 25.8 years, with a mean of 11.1 years.

All of the subjects in this sample were evaluated by otolaryngologists to affirm passive airway obstruction resulting from at least one of the following airway pathologies: adenoid hyperplasia, tonsil hyperplasia, turbinate hyperplasia, deviated nasal septum, or allergic rhinitis.

Lateral cephalographs and dental casts from the files of the Case Western Reserve University Orthodontic Clinic and four private orthodontic practitioners were available for all subjects. In addition, posteroanterior cephalographs for 55 of the individuals were made.

The breathing-impaired sample was further grouped into samples A and B. The 37 subjects in subsample A had no history of orthodontic treatment. Rhinomanometric records were available for each subject (CHENG 1988). All of the 34 subjects in subsample B were under active orthodontic treatment. Pretreatment cephalometric radiographs and dental casts were utilized for the evaluation of this sample.

The control sample was selected from the longitudinal records of the Bolton Study at Case Western Reserve University, Cleveland, Ohio. Age and sex distributions were comparable with the breathing-impaired sample. The age range was 3.9 to 33.1 years, with a mean of 11.0 years. The control sample subjects were all Caucasian and met the following criteria: no history of orthodontic treatment, no history of mouth breathing or any airway impairments, and a complete set of records available for each subject including lateral and P-A cephalographs and maxillary and mandibular casts.

All cephalometric tracings were made by the first author. Forty-four linear, angular and ratio values dealing with nasopharyngeal airway size, craniofacial relationships, and dentoalveolar pattern were determined. From the study casts, overjet, overbite, maxillary intercuspid and intermolar widths, mandibular intercuspid and intermolar widths, palatal width including Angle classifications, crossbites and crowding were also measured. Definitions and explanations for these cephalometric and dental cast variables were based on CHENG (1988).

Statistical analyses were performed at the Jennings Computer Center, Case Western Reserve University using SPSSX (Statistical Package for Social Science)

Student's t-test and the Chi-square test were used to compare craniofacial and occlusal patterns between the breathing-impaired and control groups.

In the breathing-impaired sample, the differences between subsample A and B were tested by analysis of variance (MAN OVA). Craniofacial and occlusal variables showing a significant difference ($p < .05$) between the impaired and control groups were tested further for relationships with the age variable by means of the Pearson correlation method.

To test for close relationships between specific types of malocclusions and certain craniofacial combinations, univariate and multivariate analyses were performed sequentially to obtain multiple regression equations or discriminate functions.

In these multivariate analyses, the occlusal variables were the dependent variable (regressand) and the craniofacial variables were the independent variable (regressor).

— Findings —

Means and standard deviations for the cephalometric and occlusal variables are presented in Tables 1, 2 and 3. As seen in Table 1, the breathing-impaired group had a significantly smaller nasopharyngeal airway size ($p = 0.00$), a greater nasopharyngeal height ($p = 0.000$), a larger midcranial base angle ($p = 0.030$), and vertically longer and transversely more narrow craniofacial characteristics than the controls.

In the nasally-impaired subjects, variables related to the mandible demonstrated a longer whole mandible size,

Table 1

Cephalometric Variables Recorded From Breathing Impaired and Control Samples
Mean Values ± Standard Deviations and P Values

Cephalometric variable	Impaired (n=71)	Controls (N=71)	P value (T test)
Nasopharyngeal airway (N_pA)	4.85± 4.67	9.95±3.03	0.000***
Nasopharyngeal depth (N_pD)	58.49± 5.99	60.00±4.87	0.101
Nasopharyngeal height (N_pH)	64.59± 5.48	60.48±4.53	0.000***
Nasal width (NW)	25.75± 2.78	26.51±3.18	0.163
Nasal height (NH)	43.70± 5.28	42.24±3.90	0.064
Nasal length (NL)	53.89± 4.17	54.01±4.51	0.862
Nasal airway index (NAI)	59.81± 6.67	62.97±6.87	0.011*
Nasal airway volume index (NAVI)	31.06± 7.82	30.88±7.61	0.897
Cranial width (CW)	145.67± 6.07	150.90±6.58	0.000***
Cranial length (CL)	193.52± 8.73	188.40±8.28	0.000***
Cranial index (CI)	75.37± 3.87	80.22±3.88	0.000***
Midcranial base angle (MCBA)	41.61± 4.46	40.19±3.16	0.030*
Cranial base tipping angle (CBTA)	26.55± 2.88	25.60±2.63	0.043*
Interlateral orbital width (IlO)	88.17± 5.47	89.97±4.65	0.049*
Intermedial orbital width (ImO)	20.54± 2.48	21.16±2.38	0.155
Facial width (FW)	121.67± 6.60	125.52±7.62	0.004**
Anterior facial height (AFH)	115.52±10.70	107.33±8.20	0.000***
Facial index (FI)	93.75± 6.82	85.41±5.06	0.000***
Lower anterior facial height (LAFH)	67.84± 7.94	60.32±4.92	0.000***
Anterior facial height index (AFHI)	58.66± 2.98	56.25±2.19	0.000***
Posterior facial height (PFH)	69.77± 6.95	70.44±6.83	0.564
Posterior facial height index (PFHI)	60.80± 5.40	65.49±3.52	0.000***
Facial axis angle (FAA)	86.75± 4.87	89.80±7.47	0.005**
S–N to mandibular plane angle (S–N/MP)	39.06± 5.80	32.19±4.10	0.000***
Ramal plane to palatal plane (RP/PP)	81.29± 7.22	79.17±5.13	0.046*
Gonial angle (GA)	130.08± 6.53	125.55±6.10	0.000***
Mandibular whole length (MwL)	100.87± 7.82	97.98±8.01	0.031*
Mandibular width (MW)	90.07± 8.15	90.97±8.40	0.550
Mandibular index (MI)	89.75± 6.13	92.96±6.00	0.004**
Mandibular ramus length (MRL)	40.38± 4.81	40.88±4.76	0.535
Mandibular corpus length (MCL)	72.04± 5.90	71.21±7.64	0.473
Antegonial notch height (AG)	2.13± 0.99	1.25±0.61	0.000***
Chin protruberance (CP)	1.85± 1.17	2.06±0.91	0.250
A–N–B	3.61± 3.03	3.18±2.14	0.340
Upper anterior dental height (UADH)	28.34± 3.83	25.80±2.74	0.000***
Upper posterior dental height (UPDH)	16.77± 2.20	15.07±1.45	0.000***
Lower anterior dental height (LADH)	40.68± 4.43	37.72±3.28	0.000***
Lower posterior dental height (LPDH)	30.08± 3.41	29.48±2.82	0.250
U1/S–N angle (U1/S–N)	102.33± 7.90	103.03±7.32	0.586
LI/MP angle (LI/MP)	86.94± 8.13	91.82±6.01	0.000***
A/B Facial types (ArAB)	−3.76± 3.42	−1.27±2.65	0.000***
Ramus alignment (Ram)	2.47± 1.94	1.59±1.40	0.002***
Maxillary/Mandibular arch lengths (MxMd)	−2.88± 4.64	−0.59±3.68	0.001***
Occlusal plane alignment (OPAl)	−4.34± 4.29	−1.49±2.65	0.000***

* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

Table 2

Continuous Occlusal Variables from Dental Casts
Breathing Impaired and Control samples
Mean Values ± Standard Deviations and P values

Variable	Impaired (n=71)	Controls (N=71)	P value (T test)
Overjet	3.47±2.87	3.01±1.17	0.120***
Overbite	1.04±2.70	3.61±1.37	0.000***
Maxillary intermolar width	43.10±3.34	45.52±2.62	0.000***
Mandibular intercuspid width	40.20±3.00	39.93±2.84	0.618
Maxillary intercuspid width	30.92±3.76	32.43±2.74	0.012*
Mandibular intercuspid width	25.10±2.62	25.32±1.85	0.594
Palatal width	29.95±3.63	32.15±2.21	0.000***
Palatal height	16.17±1.61		

* P≤0.05 ** P<0.01 *** P<0.001

Table 3

Categorical Occlusal Variables from Breathing Impaired and Control Samples
Chi, Degree of Freedom, and P Values

Variable	X	D. F.	P value
Angle classification	1.09	2	0.580
Posterior lingual crossbite	25.02	1	0.000***
Anterior crossbite	16.43	1	0.000***
Maxillary anterior crowding	34.58	1	0.000***
Mandibular anterior crowding	5.48	1	0.019*

deeper antegonial notching, and the gonial angle was larger. All of the upper dental heights, and the lower anterior dental heights, were significantly greater than in the control subjects (p=0.000). The lower incisors were also more upright, and the L1/mandibular plane angle was smaller.

The breathing-impaired subjects showed a predominance of facial type B, with mandibular point B more anterior than maxillary point A as determined from a perpendicular to the functional occlusal plane. Also, a greater degree of backward/downward alignment position of the mandible, a relatively longer mandibular arch length, and a more steep occlusal plane existed.

From cast measurements (Tables 2 and 3), the breathing-impaired subjects demonstrated a more shallow vertical overbite, more narrow maxillary intermolar and intercuspid widths, a narrower and deeper palate, a more severe posterior lingual crossbite, and more frequent anterior crossbite and crowded maxillary and mandibular anterior teeth than the control subjects.

The results of the MANOVA test demonstrate no significant differences among the craniofacial (p=0.289) and occlusal (p=0.112) variables between the subsample A and subsample B groups.

As seen in Table 4, the cranial index also showed significant correlations with several craniofacial and dental variables (p<.05). The results indicate that the dolichofacial headform is associated with a longer nasal length, a longer anterior facial height, a more leptoprosopic face, and a higher mandibular plane angle.

Cranial width of the breathing-impaired subjects also showed highly significant associations with most transverse facial dimensions, including interorbital width ($p=0.007$), interlateral orbital width ($p=0.000$), facial width ($p=0.000$) and mandibular bigonial width ($p=0.000$).

Table 4

Breathing-Impaired Sample
Pearson Correlation Coefficients (r) for Cephalometric Variables (regressors) and Cranial Index (regressand)

Regressor Variable	Regressand Cranial Index r
Nasal length	−0.48***
Cranial width	0.47***
Cranial length	−0.65***
Anterior facial height	−0.34**
Facial index	−0.44***
Lower anterior facial height	−0.32**
Posterior facial height	−0.26**
Mandibular whole length	−0.46***
Mandibular index	0.36**
Mandibular ramus length	−0.25*
Mandibular corpus length	−0.23*
S–N / Mandibular plane angle	−0.23*
Upper anterior dental height	−0.22*
Lower anterior dental height	−0.37**
Lower posterior dental height	−0.38**
Occlusal plane alignment	0.25*

In the breathing-impaired sample, Black subjects had a significantly larger midcranial base angle ($p=0.025$), longer lower anterior facial height ($p=0.003$), longer mandibular corpus length ($p<0.010$), a larger antegonial notch ($p=0.025$) and a smaller gonial angle ($p=0.016$) than Caucasians.

As shown in Table 5, the relationships among age and selected craniofacial dental variables demonstrated significantly shorter linear measurements for nasopharyngeal airway size, cranial length, lower anterior facial height, mandibular whole length, dental heights, intercuspid width and palatal height in the younger breathing-impaired subjects ($p<.05$). The younger subjects also showed less crowding in both maxillary and mandibular anterior dentitions, a more brachycephalic head form, and a more euryprosopic facial pattern.

The smaller midcranial base angle, lesser upward tilt of the cranial base, larger facial axis angle, smaller mandibular plane angle, and smaller ramal plane / palatal plane angle were also noted in the younger breathing-impaired subjects.

As seen in Table 6, the results of multivariate analyses show very significant correlations ($p=0.000$) for vertical overbite, maxillary intermolar and intercuspid widths, palate width, palate height, crossbite, and anterior crowding with several craniofacial combinations.

The R^2 value of these five multiple regression functions varied from 0.20 to 0.65. The high R^2 value (0.65) for the palate height equation indicates that 65% of the variations in height of the palate could be explained by the variations in mandibular corpus length (BL), the Ramus / middle cranial fossa horizontal comparison, and anterior facial height (AFH).

Discriminant score functions demonstrate that the anatomic groupings for the incidence of crossbite and anterior crowding were 63.2% to 89.6% accurate.

Total nasal resistance as determined by rhinomanometry is a reliable indicator of severity of airway obstruction. In the present study, although high resistance values (greater than 3.5cm H_2O/liter/second) existed in the airway-affected sample, clear-cut linear relationships between the magnitude of resistance and the severities of the deformities that also existed were not observed.

Table 5

Pearson Correlation Coeffecients (r) for Variables showing Significant Differences between Impaired and Controls (regressors) and Age (regressand) in Impaired Group

Regressor Variable	Regressand Age r
Nasopharyngeal airway size	0.60**
Nasopharyngeal height	0.08
Nasal airway	0.00
Cranial width	0.06
Cranial length	0.26*
Cranial index	−2.34*
Midcranial base angle	−0.52*
Cranial base tipping angle	−0.78
Interlateral orbital width	0.33**
Facial width	0.59***
Anterior facial height	0.52***
Facial index	0.30*
Lower anterior facial height	0.33**
Anterior facial height index	−0.20*
Posterior facial height index	0.06
Facial axis angle	−0.07
S–N / Mandibular plane angle	0.01
Ramus plane to palatal plane	0.14
Gonial angle	−0.18
Mandibular whole length	0.54***
Mandibular index	0.05***
Height of the antegonial notch	0.18***
Upper anterior dental height	0.31**
Upper posterior dental height	0.48***
Lower anterior dental height	0.41***
LI/MP angle	0.19***
A/B Facial types	0.04
Ramus alignment	0.07
Maxillary/Mandibular arch length	−0.12
Occlusal plane alignment	−0.07
Overbite	0.24*
Maxillary intermolar width	−0.09
Maxillary intercuspid width	0.23*
Palate width	−0.50*
Palate height	0.52***
Posterior lingual crossbite	0.13
Anterior crossbite	0.09
Maxillary anterior crowding	0.46***
Mandibular anterior crowding	0.50***

While important in the diagnosis of obstruction, it must be noted that our rhinomanometric data were limited to one point in time and thus do not reflect the dynamic changes which may occur during progressive growth. A longitudinal study is necessary to clarify biologic relationships between nasal resistance values and degrees of variation in associated dentofacial morphology.

— Discussion —

Of the variables studied, 30 cephalometric and 8 dental cast variables showed significant differences between the impaired and control groups. The breathing-impaired subjects demonstrated smaller sagittal depths and larger sagittal height angles of the bony nasopharynx than the controls.

These findings support the observations of Linder-Aronson (1979), who concluded that the sagittal depth of the nasopharynx is less in the mouth-breathing subject.

Bushey (1979) found that the sagittal height of the nasopharynx was less in breathing-impaired subjects and suggested that the angular height of the nasopharynx appears to be a valid discriminating factor among different respiratory groups. The apparently conflicting findings with regard to nasopharyngeal height in breathing-impaired subjects need further study.

Anteroposterior and vertical craniofacial characteristics in breathing-impaired subjects have been discussed extensively (Linder-Aronson 1979; Watson et al. 1968). However, there is still relatively scant information dealing with quantitative measures of transverse craniofacial dimensions in subjects with nasal or pharyngeal obstruction.

In our study, P–A cephalographs in 55 of the impaired group and 71 of the control group provide some additional basic information on transverse dimensions of certain craniofacial components and facial proportions. In the breathing-impaired subjects, the more narrow cranial and facial widths contribute to the long-face appearance of the mouth breathers. The cranial index shows high correlations with dentofacial morphology.

The more dolichocephalic the head form, the more leptoprosopic is the face, with longer nasal and mandibular whole lengths, and longer facial and dentoalveolar heights. Steeper mandibular and occlusal planes also relate to the dolichocephalic headform.

These 3-dimensional relationships demonstrate the close nature of relationships between headform and facial morphology (Bhat and Enlow 1985).

Cranial width also has significant associations with the interorbital, interlateral orbital, facial, and mandibular bigonial widths. These findings agree with relationships described by Enlow (1982) in which boundaries of the midface coincide with respective brain and basicranial boundaries.

The shape and size of the mandible in the breathing-compromised subjects show significant differences from the controls. Their mandibles are longer, with larger gonial angles and deeper antegonial notches. Also, the mandibular arch is larger relative to the maxillary arch. There is a "B" facial type tendency among the breathing-impaired individuals, reflecting these mandibular features and the brachyfacial tendency.

However, there was not a higher incidence of Class III malocclusion in this particular breathing-impaired sample, since the overall mandibular protrusive effects tend to be offset by the greater vertical face heights and backward alignment placement of the whole mandible.

All dentoalveolar heights were larger in the impaired group. This appears to be a dental adjustment related to increased midfacial skeletal height (Enlow 1982). Narrower maxillary dental arch and palate widths were noted in the impaired group. Palate height could not be determined from casts of the control sample because of limitations due to the impression technique. However, a high correlation between palate height and posterior dental height ($r=0.93$) obtained from lateral cephalographs permitted substitution of palate height for UPDH. The significantly higher UPDH in the impaired subjects demonstrates higher palatal heights than in the control subjects.

The higher incidence of posterior lingual crossbite in our study supports a similar finding by Melsen et al. (1987).

In our study, the breathing-impaired subjects showed more upright lower anterior teeth and more anterior crowding than the controls. Linder-Aronson et al. (1986) suggest that some forms of incisor crowding previously attributed to tooth/jaw size discrepancies might represent environmental crowding which could be managed without permanent tooth extraction. The higher incidence of anterior crowding in breathing-impaired subjects might be due to the narrowed maxillary arch and aberrant muscle function. Early correction of the nasal or nasopharyngeal obstruction might decrease tendencies for relapse of lower incisor crowding following orthodontic treatment in such individuals.

Fifteen Black subjects were included in the breathing-impaired group. They showed a relatively longer mandibular corpus length, and wider dental arch and palate widths than the Caucasians. These findings might relate to the larger tongue size also seen in Black populations (Drummond 1968).

Table 6

Multiple Regressions and Discriminant Score Functions of Selected Dental Cast Variables in Breathing Impaired Sample

Multiple regression functions	R	R^2	P
Overbite = 24.92 − 0.41AFHI	0.45	0.20	0.000***
Maxillary intermolar width = 21.41 + 0.17MCL − 0.85AG + 0.27MCBA	0.54	0.29	0.000***
Maxillary intercuspid width = 35.52 + 0.27NpH − 0.26MI + 1.09CP	0.69	0.48	0.000***
Palate width = 6.41 + 0.19MCL − 0.90AG + 0.29MCBA	0.53	0.29	0.000***
Palate height = − 10.17 + 0.13MCL + 0.24RMCF + 0.14AFH	0.81	0.65	0.000***

Discriminant score functions	Percent of accurate prediction	P
Posterior lingual crossbite = − 19.44 + 0.13RMCF + 0.09PFH + 0.15N_pH + 0.11N_pD	63.24%	0.004**
Anterior crossbite = 4.27 + 0.32ANB − 0.20CBT	69.12%	0.000***
Maxillary anterior crowding = − 6.58 + 0.18RMCF + 0.53CP − 0.11LAFH + 0.07PFH + 0.15FI − 0.15MCBA − 0.11NAV + 0.07N_pH	86.96%	0.000***
Mandibular anterior crowding = − 1.19 + 0.09RMCF + 0.05MI − 0.13LAFH − 0.162FA + 0.15AFH − 0.09MCBA + 0.10N_pD	89.58%	0.000***

Greater lower anterior facial height, more procumbent maxillary and mandibular incisors, and more backward rotation of the mandibular rami found in our Black impaired sample also support similar findings by ALEXANDER AND HITCHCOCK (1978).

Since the control group was composed of Caucasian subjects only, the differences in craniofacial and occlusal characteristics between Black and Caucasian subjects should be taken into account in our comparisons between the caucasoid-only controls and the mixed impaired group.

It is interesting to note that the younger a subject is at the time of evaluation, the less the "adenoid" type of facial characteristics are expressed. The younger subjects demonstrate a lesser degree of leptoprosopic facial appearance, since transverse dimensions become established earlier than vertical. They also had less open bite tendency and a less anterior crowding.

All of these multiple conditions in younger children also relate to the detrimental effects of an obstructive airway, which are not yet fully established. This observation underscores the importance of early diagnosis and treatment of breathing-impaired individuals.

The hypothesis that specific types of malocclusions found in breathing-compromised subjects relate to certain intrinsic combinations of morphologic features was tested with multivariate analyses. Results from the multiple regression equations (Table 6) show that vertical overbite, maxillary intermolar width, maxillary intercuspid width, and palate width all correlate highly with certain intrinsic morphologic combinations (p = 0.000).

The equation of overbite = 24.92 − 0.41AFHI demonstrates a negative association of the anterior facial height index with overbite. The larger the anterior facial height index (AFHI), the more shallow the vertical overbite.

The equation of maxillary intermolar width = 21.41 + 0.17MCL − 0.85AG + 0.27MCBA shows that the longer the mandible corpus length (MCL), the lower the depth of the antegonial notch (AG), and that the larger the midcranial base angle (MCBA), the wider the maxillary intermolar width.

The equations that relate to the maxillary intercuspid width and palatal width also demonstrate a close relationship with the *combinations* of NpH, MI, CP; MCL, AG, MCBA, respectively.

The height of the antegonial notch (AG) and the midcranial base angle (MCBA) are both noted in the equations of maxillary intermolar and palatal width which relate to the transverse dimensions of the maxillary dental arch or palate. The high incidence of AG, MCBA found in these equations suggests that an intimate relationship exists between the antegonial notch, midcranial base angle and the transverse maxillary dimension. The higher the value of the AG, the greater the likelihood of a narrow maxillary dental arch or palate. The higher the value of the MCBA, the greater is the tendency to have a wider maxillary dental arch or palate.

This finding conflicts with other results (Table 1), which show that the breathing-impaired subjects had a larger midcranial base angle in conjunction with a narrow maxillary dental arch and palate. The nature of the influence of the MCBA on the etiology of malocclusion thus requires further study.

The equation of palate height = − 10.17 + 0.13MDL + 0.24RMCF + 0.14AFH had a very high R^2 score. This significant value suggests that using mandibular corpus length (MCL), Ramus/MCF horizontal skeletal dimensions (RMCF), and anterior facial height (AFH) to predict the value of palate height, will provide an acceptable degree of accuracy for prediction of palate height. This equation also shows that individuals with larger MCL, RMCF and AFH values have a tendency for a higher palatal vault.

Since the crossbite and anterior crowding data were dichotomous variables, discriminant analysis was used to test the relationships between the existence of crossbite or anterior crowding and the craniofacial variables. A discriminant score was calculated first, and then Bayes's Rule was used to classify subjects into one of the two groups. The relationship among the + or − signs of the craniofacial variables and the grouping of the crossbite or anterior crowding were determined from those results.

The results also show a high correlation between posterior lingual crossbite and RMCF, PFH, NpH, NpD; anterior crossbite and ANB, CBT; maxillary anterior crowding and RMCF, CP, LAFH, PFH, FI, MCBA, NAV, NpH; mandibular anterior crowding and RMCF, MI, LAFH, FA, AFH, MCBA, NpD.

Based on our study sample, the correct prediction percentage was 63.2% for grouping posterior lingual crossbite; 69.1% for grouping anterior crossbite; 87.0% for grouping maxillary anterior crowding and 89.6% for grouping mandibular anterior crowding.

These high accuracy values for grouping crossbites and anterior crowding, and the high R^2 score for the palate height equation suggest that a future onset of specific types of malocclusion (palate height, crossbite and anterior crowding) can be expected if these characteristic combinations of morphologic components are found in a young child.

— Summary and Conclusions —

This study characterizes craniofacial morphology and occlusal patterns in breathing-impaired subjects and tests a hypothesis that specific types of malocclusions found in subjects with nasal obstruction relate to certain intrinsic morphologic combinations.

The findings lead to the following conclusions:

- Craniofacial morphology and occlusal patterns in the breathing-impaired sample are significantly different from those in the control sample. The discrepancies relate to vertical components associated with a longer face and dentoalveolar and palatal heights. Transversely, the impaired subjects also show more narrow cranial and palatal widths. The mandibles in these subjects were characterized by greater whole mandibular length and more prominent antegonial notching.
- In the breathing-impaired group, Black subjects showed a larger mandibular length, wider dental arches and palates, a larger midcranial base angle, and a more backward alignment of the mandibular rami.
- The younger a breathing-impaired subject, the less marked is the expression of these craniofacial morphologic and occlusal characteristics.
- The results of multivariate analyses show high correlations of certain types of occlusal variables with specific combinations of craniofacial structures. High prediction rates for palate height and accurate groupings for posterior lingual crossbite, anterior crossbite, maxillary anterior crowding, and mandibular anterior crowding are achieved through utilization of certain combinations of craniofacial morphologic variables.
- A multidisciplinary approach involving the otolaryngologist and the orthodontist is advantageous for curtailing or reducing continuing detrimental effects of breathing impairments on craniofacial morphology and occlusion.

References

Alexander, T. L. and Hitchcock, H. P. 1978. Cephalometric standards for American Negro children. *Am. J. Orthod.* 74:298-304.

Bench, R. W., Gugino, C. F., and Hilgers, J. J. 1977. Bio-progressive therapy (Part 4). *J. Clin. Orthod.* 11:820-834.

Bhat, M., and Enlow, D. H. 1985. Facial variations related to headform type. *Angle Orthod.* 55:269-280.

Bushey, R. S. 1979. Diagnosis and treatment planning of nasopharyngeal obstruction. In: *Naso-respiratory Function and Craniofacial Growth.* J. A. McNamara, Jr. (Ed.). Craniofacial Growth Series, Center for Human Growth and Development, The University of Michigan, Ann Arbor, 301-322.

Cheng, M. C. 1988. *Evaluation of craniofacial morphology and occlusion in patients with nasal obstruction.* Master's Thesis, Case Western Reserve University.

Drummond, R. A. 1968. A determination of cephalometric norms for the Negro race. *Am. J. Orthod.* 54:670-682.

Enlow, D. H., Kuroda, T. and Lewis, A. G. 1971a. The morphological and morphogenic basis for craniofacial form and pattern. *Angle Orthod.* 41:161-188.

Enlow, D. H., Kuroda, T. and Lewis, A. B. 1971b. Intrinsic craniofacial compensations. *Angle Orthod.* 41:271-285.

Enlow, D. H. 1982. *Handbook of Facial Growth.* W.B. Saunders, 2nd Ed.

Harvold, E. P., Vargervik, K. and Chierici, G. 1973. Primate experiments on oral sensation and dental malocclusions. *Am. J. Orthod.* 63:494-508.

Harvold, E. P. 1975. Experiments on mandibular morphogenesis. In: *Determinants of Mandibular Form and Growth.* J. A. McNamara, Jr. (ed.). Craniofacial Growth Series, Center for Human Growth and Development. The University of Michigan, Ann Arbor, 155-177.

Harvold, E. P. 1979. Neuromuscular and morphological adaptations in experimentally induced oral respiration. In: *Naso-respiratory function and craniofacial growth.* J. A. McNamara, Jr. (ed.). Craniofacial Growth Series, Center for Human Growth and Development. The University of Michigan, Ann Arbor, 149-164.

Harvold, E. P., Tomer, B. S., Chierici, G. and Vargervik, K. 1981. Primate experiments in oral respiration. *Am. J. Orthod.* 79:359-372.

Huber, R. E. and Reynolds, J. W. 1946. A dentofacial study of male students at the University of Michigan in the physical hardening program. *Am. J. Orthod. and Oral Surg.* 32:1-21.

Ingervall, B. and Thilander, B. 1974. Relation between facial morphology and activity of the masticatory muscles (Electromyographic and radiographic cephalometric investigation). *Annals of Oral Rehabil.* 1:131-147.

Leech, H. L. 1958. A clinical analysis of orofacial morphology and behavior of 500 patients attending an upper respiratory clinic. *Dent. Prac.* 9:57-68.

Linder-Aronson, S. 1970. Adenoids: Their effect on mode of breathing and nasal airflow and their relationship to characteristics of the facial skeleton and the dentition. *Acta Oto-Laryng.* Suppl. 365:3-132.

Linder-Aronson, S. 1979. Respiratory function in relation to facial morphology and the dentition. *Brit. J. of Orthod.* 6:59-71.

Linder-Aronson, S. 1986. Nasorespiratory considerations in orthodontics. In: *Orthodontics, state of the art, essence of the science.* ed. by Lee W. Graber, 116-121.

McNamara, J. A. 1981. Influence of respiratory pattern on craniofacial growth. *Angle Orthod.* 51:269-300.

Melsen, B., Attina, L., Santuari, M. and Attina, A. 1987. Relationships between swallowing pattern, mode of respiration and development of malocclusion. *Angle Orthod.* 57:113-120.

Miller, A. J., and Vargervik, K. 1979. Neuromuscular changes during long-term adaptation of the rhesus monkey to oral respiration. In: *Naso-respiratory function and craniofacial growth.* J. A. McNamara, Jr. (ed.). Craniofacial Growth Series. Center for Human Growth and Development, The University of Michigan, Ann Arbor, 1-26.

O'Ray, F. S., Gallagher, D. M., LaBanc, J. P. and Epker, B. N. 1982. The relation between nasorespiratory function and dentofacial morphology: A review. *Am. J. Orthod.* 82:403-410.

Shaughnessy, T. G. 1983. The relationship between upper airway obstruction and craniofacial growth. *J. Mich. Dent. Assoc.* 65:431-433.

Tallgren, A. 1970. Alveolar bone loss in denture wearers as related to facial morphology. *Acta Odont. Scand.* 28:251.

Trouten, J. C., Enlow, D. H., Rabine, M., Phelps, A. E. and Swedlow, D. 1983. Morphologic factors in open bite and deep bite. *Angle Orthod.* 53:192-211.

Vig, P. S., Sarver, D. M., Hall, D. J. and Warren, D. W. 1981. Quantitative evaluation of nasal airflow in relation to facial morphology. *Am. J. Orthod.* 79:263-271.

Warren, D. W., Oehman, M. D., and Hinton, V. A. 1984. Analysis of simulated upper airway breathing. *Am. J. Orthod.* 86:197-206.

Watson, R. M., Warren, D. W., Fisher, N. D. 1968. Nasal resistance skeletal classification and mouthbreathing in orthodontic patients. *Am. J. Orthod.* 54:367 – 379.