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Original Research

Immediate Postural Responses to Total Nasal Obstruction: A Cephalometric Study

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Abstract:
Background: Nasal respiratory impairment has been associated with a deviant vertical craniofacial growth pattern along with various dento-alveolar malocclusions for a century. Respiratory needs are the primary determinant of the posture of the jaws, tongue, and head. Therefore, it seems entirely reasonable that an altered respiratory pattern such as breathing through the mouth rather than the nose could change the posture. This in turn could rather alter the equilibrium of pressure on the cranium, jaws and teeth position, which might lead to various malocclusions. The objective of the present study was to radiographically measure the nature and the extent of the postural reflexive behavior of cranium, tongue, mandible, hyoid bone, and lips after total nasal obstruction.

Materials and Methods: A total of 25 nasal breathing adults were radiographically examined before and after their nasal respiratory pattern had been artificially eliminated for a period of 1-h, radiographs were taken in natural head position. Six angular and six linear variables were measured to determine the extent of the postural reflexive behavior of the cranium, mandible, hyoid bone, tongue, and lips.

Results: All subjects coped in their own individual way with the environmental impact. The most generalized findings were parting of the lips ($P < 0.001$), a drop in mandibular position ($P < 0.001$), downward movement of the hyoid bone ($P < 0.05$), downward movement of tongue ($P < 0.001$), cranial extension, and craniocervical extension were statistically highly significant ($P = 0.001$). The relevance of these findings relative to primate experiments and human clinical research is discussed.

Conclusion: If the same postural reactions are maintained over a long-term period, they may be instrumental in influencing the vertical craniofacial growth pattern.

Key Words: Head extension, malocclusion, mouth breathing, nasal obstruction, postural changes, vertical craniofacial changes

Introduction

The history of orthodontics, like that of other health-related professions, can be viewed as an evolutionary progression from art to a biomedical science. As the challenge of creating ever-more efficient treatment methods is met, attention becomes more firmly fixed on etiology and the possibility of prevention. After several decades, during which it was generally believed that heredity immutably determines the craniofacial form, today's prevailing views are somewhat more optimistic. Currently, research efforts and some clinical practices are aimed at testing the premise that not only is growth and development modifiable but variations in morphology are determined, at least in part, by postnatal environmental influences. Confirmation of this premise, if followed by an adequate explanation of its mechanism, has profound implications for the future of orthodontics. Obviously, our present role of being mainly concerned with the correction of anomalies which really reflect the signs and symptoms of etiology would be superseded by the primary objective of growth modification and regulation.

While it is true that we are still a long way from this situation, the present study and other work in progress stem from significant contributions of others toward the realization of such a goal.

Two major physiologic factors – posture and respiration – have been implicated as possible modifying influences in the control of growth and the establishment of dentofacial morphology.

Oral respiration associated with obstruction of the nasal airway is a common finding among patients seeking orthodontic treatment. Nasal respiratory impairment has been associated with a deviant vertical craniofacial growth pattern for at least a century. An increase in anterior face height[1] and in gonial angle,[2] along with a decrease in facial prognathism,[3] are commonly described features. The morphologic changes may be induced by an alteration in craniofacial muscle recruitment or by a soft tissue stretching mechanism.[4] These functional responses, in turn, could be elicited by postural reflexive mechanisms that facilitate passage of air through the oropharynx.[5] This environmental concept of vertical craniofacial growth has been corroborated by some clinical studies that have indeed found associations between naso-respiratory impairment and postural variables.[6] However, controversy still remains about the validity of contemporary methods for quantifying the oronasal breathing ratio[7] and the cause and effect relationship between oronasal breathing, postural behaviors, and skeletal structure.[8]

Nasal obstruction and oral breathing have long been clinically implicated, albeit without a good explanation, as a part of a syndrome consisting of a long lower face height, a high narrow palatal vault, and an open-bite malocclusion. In addition, with the exception of the studies of Vig *et al*.[9] and of Hellsing *et al*.,[10] the postural reactions after nasal obstruction have never been experimentally studied in human beings. This study is one of the attempts to radiographically measure nature and the extent of those reflexes within a controlled experimental setting.

Materials and Methods

This study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, A. B. Shetty Memorial Institute of Dental Sciences, Deralakatte, Mangalore, Karnataka.

The group of 25 adults (9 women and 16 men) volunteers participated in the study. The ages ranged from 23.7 to 29.9 years, with a mean of 26.8 years. All subjects who participated in this study were volunteers from A.B. Shetty Memorial Institute of Dental Sciences.

None of the subjects revealed any previous history of difficulty in breathing through the nose.

All the subjects had lip contact at rest. On examination, none of the subjects reported with habitual mouth opening, enlarged adenoids, nasal polyps, deviated nasal septum, inflammatory mucosa, carcinoma, or any upper and lower respiratory tract obstruction.

A pre-experimental reference lateral cephalometric radiograph was taken with each subject standing with their head held in a natural position as obtained by the "self-balancing method."[11]

Roentgenographic technique

The radiographic equipment consisted of the motorized, vertically adjustable planmeca – 2002 series, anode X-ray source with a focus of 0.8 mm. The vertical adjustability permits the recording of standing subjects. An metal chain suspending a weight was mounted in front of the cassette to indicate the true vertical on the film. The transverse adjustment of the head in the cephalostat is facilitated by a light source projecting a horizontal line through the plane of the ear rods and a vertical line through the median plane of the head holder. The focus-median plane distance was 180 cm and the film-median plane distance was 10 cm for the lateral cephalometric films with an enlargement of 5.6%. A movable grid and a wedge-shaped aluminum filter in front of the cassette were used to enhance image quality.

Positioning procedure

The recording of lateral cephalometric radiographs in the natural head posture were carried out as described, the steps of the positioning procedure are listed below.

Rehearsal of posture

Body posture

Standing position with heels together and let the arms hang, tense patients were instructed to "walk on the spot" and perhaps to raise and drop shoulders to ease tension (Figure 1).

Head posture

Subject's head were held in a natural head position (NHP); that is, the head position is defined by proprioceptive information from muscles and ligaments and possibly also from the utricular and semicircular canal systems. The position thus obtained has been termed the self-balance position. The second phase of the rehearsal sequence consists of the rehearsal of the self-balance position of the head. During the rehearsal of this head posture. All subjects were instructed to find this position by tilting the head forward and backward with decreasing amplitude until the most neutral and comfortable position is reached.

Positioning in the cephalometer

After the rehearsal of the orthoposition of the body and the self-balance position of the head, subjects were positioned in the cephalometer.

Positioning of the feet

Subjects first walked in and placed under the raised head holder. To avoid spoiling the established position, the rods were not inserted into the acoustic meatus but reversed to support the head from both sides by lightly touching the ears.

Body-positioning and head-positioning

These procedures, rehearsed outside the cephalometer, were repeated, and the subject was then instructed to "hold their head in that neutral and comfortable position." This defines the self-balance position. The natural rest position of the mandible

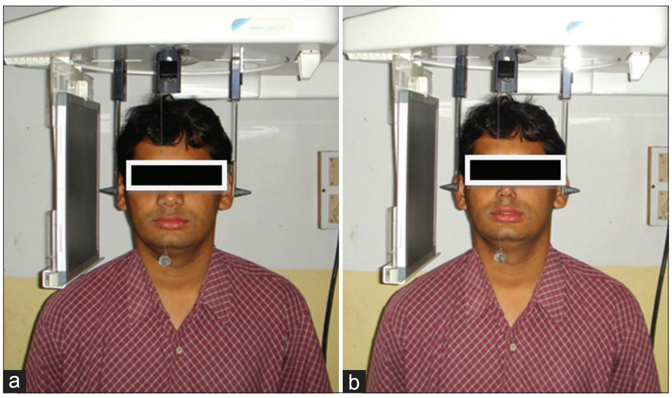


Figure 1: Subject positioned in natural head position during roentgenographic technique, (a) pre-experimental, (b) post-experimental (with nose clip).

was standardized by having the subject pronounce the word Mississippi, Mysore.

Adjustment for symmetry

This is finally carried out with guidance by the light-beam cross projected onto the face while at the same time care is taken to ensure that the sagittal position of the head is not disturbed.

At the end of which the radiograph was exposed. Each subject's nose was then blocked with a nose clip of the type commonly used by swimmers. After a 1-h period, the same technique was used to take a second lateral cephalogram of the nasally obstructed subject. The cephalograms were traced and appropriate landmarks identified (Table 1 and Figure 2) to construct 11 postural variables describing the position of the craniofacial, cervical, and hyoid structures (Table 2 and Figure 2). These measurements were then compared for each subject's initial and final radiograph (Figure 3a and b).

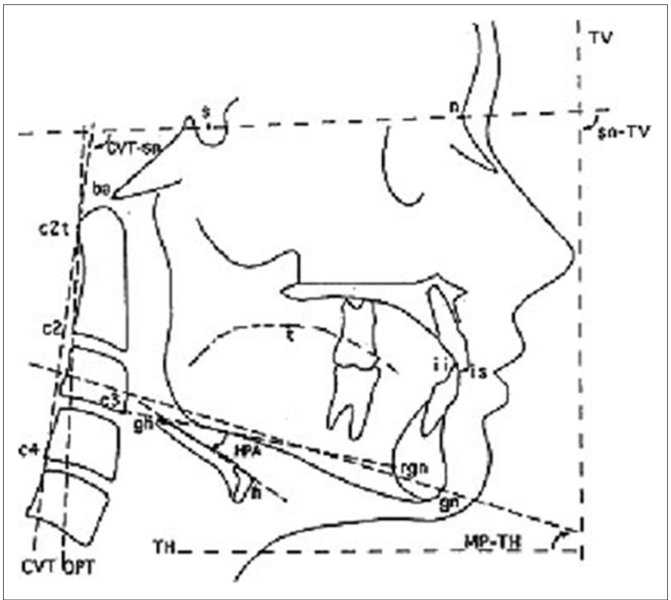


Figure 2: Landmarks and postural measurements.

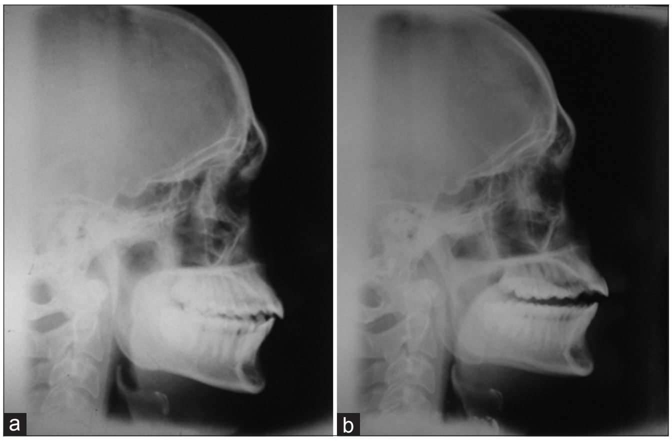


Figure 3: (a and b) Pre- and post-experimental lateral cephalograms.

Intraexaminer reliability was assessed by retracing 10 randomly selected radiographs and calculating the pooled standard deviation among duplicate measurements with Kendall's Tabu correlation coefficient test. It showed highly correlation (Significance [two-tailed] - 0.000) for all linear and angular measurements between two tracings, as shown in Table 3. All these were well within the acceptable range.

Table 1: Definition of less common landmarks.

c2 - Most interior and posterior point on the corpus of the second cervical vertebra
c3 - Most inferior and anterior point on the corpus of the third cervical vertebra
c4 - Most inferior and posterior point on the corpus of the fourth cervical vertebra
c2t - Most posterior and superior point on the dorsal side of the odontoid process
rgn - (Retrognathion) Most inferior and posterior point on the mandibular symphysis
h - (Hyoidale) Most anterior and superior point on the body of the hyoid bone
gh - Most posterior and superior point on the greater horn of hyoid bone
t - Most superior point on the tongue
OPT – (Odontoid process tangent) The posterior tangent to the odontoid process through c2 and c2t
CVT - (Cervical vertebral tangent) Line connecting cervical land mark c4 and c2t

Table 2: Definition of postural measurements.

Angles
SN-TV - The angle formed by sella-nasion and extra cranial true vertical line
SN-MP - The angle formed by sella-nasion and mandibular plane (go-gn)
MP-TH - The angle formed by the mandibular plane and extra cranial true horizontal line
H pl ang - (Hyoid plane angle) The posterior angle formed by lines h-gh and c3-rg
OPT-CVT - The angle formed by lines odontoid process tangent and cervical vertebral tangent
CVT-SN - The angle formed by lines cervical vertebral tangent and SN
Distances
MP-h - Perpendicular distance from hyoidale to the mandibular plane
i-i - Vertical distance between upper and lower incisal edges
t-MP - Perpendicular distance from t to the mandibular plane
c3-h - Distance from c3 to hyoidale
Ba-c4 - Distance from basion to c4
Stu-stl - Vertical distance between upper and lower lip

Table 3: Descriptive statistics and the significance of the difference between prenasal and postnasal blockage values.

Variables	Paired differences Mean±SD	*t* value	*P* value
SN-TV-pre SN-TV-post	4.40±4.25	5.17	0.001***
SN-MP-pre SN-MP-post	−2.80±3.40	−4.11	0.001***
MP-TH-pre MP-TH-post	1.88±5.23	1.80	0.085
h pl ang-pre h pl ang-post	−4.12±6.15	−3.35	0.003***
OPT-CVT-pre OPT-CVT-post	0.52±2.10	1.24	0.229
CVT-SN-pre CVT-SN-post	−4.40±4.62	−4.75	0.001***
MP-h-pre MP-h-post	−2.24±5.51	−2.23	0.05*
i-i-pre i-i-post	−2.20±0.76	−14.40	0.001***
t-MP-pre t-MP-post	2.88±4.06	3.55	0.001***
C3-h-pre C3-h-post	0.12±3.06	0.20	0.85
Ba-C4-pre Ba-C4-post	−0.24±3.48	−0.35	0.73
Stu-Stl-pre Stu-Stl-post	−4.68±2.21	−10.56	0.001***

*Significant, ***Highly significant, SD: Standard deviation, OPT: Odontoid process tangent, CVT: Cervical vertebral tangent, SN: Sella-nasion, TV: True vertical, MP: Mandibular plane, TH: True horizontal

To avoid extra radiation for the subjects, the reproducibility of the postural reflexes was not assessed in this study. The reliability of the natural head posture technique, however, has been documented in other research.[11,12]

The subject's postural adaptation was calculated by the differences between the pre-experimental and post-experimental values. All variables were tested for statistical significance by a paired *t*-test. The level of significance was determined at $P < 0.05$. To look for associations among the different postural reflexes, a Pearson correlation coefficient was calculated among all variables.

Positive and negative values are assigned as appropriate, depending on whether there was an increase or decrease in the value measured.

Results

This study was conducted on a cephalometric radiograph of 25 subject's ages ranging from 23.7 to 29.9 years, with a mean of 26.8 years. Pre- and post-experimental lateral cephalometric radiograph was taken with each subject standing with their head held in a natural position as obtained by the "self-balancing method," as described earlier.

Radiographs were traced manually on acetate paper. Conventional angular and linear cephalometric variables were marked on the tracing for measurements as described earlier.

Table 3 shows that the correlation of craniovertical angle (SN-TV), mandibular plane to sella-nasion (SN-MP), MP to true horizontal (MP-TH), hyoid angle (h pl angle), craniocervical angle (CVT-SN), hyoid position (MP-h), incisor position (i-i), tongue position (t-MP), lip position (stu-stul) of pre-experimental group with post-experimental group was found highly significant ($P < 0.001$).

Table 4 shows that the correlation of cranial extension (SN-TV) to craniocervical (CVT-SN), (MP-TH), h pl angle, cervical lordosis (CVT-OPT), mouth opening (i-i) was found to be significant.

The correlation of SN-MP to MP-TH, CVT-SN, t-MP and MP-TH to t-MP was found to be significant.

The correlation of MP-h to t-MP, h pl angle was found to be highly significant ($r = -0.71$, $P < 0.001$).

An increase in cranial extension (SN-TV) can be partly explained by an increase in craniocervical extension ($r = 0.48$, $P < 0.015$), and it seems to carry the mandible with it ($r = 0.52$, $P < 0.007$) along with mouth opening (i-i) ($r = 0.45$, $P < 0.024$). Increased craniocervical extension is associated with increased MP angle ($r = 0.48$, $P < 0.015$). SN-MP change can be positive while MP-TH change can be negative.

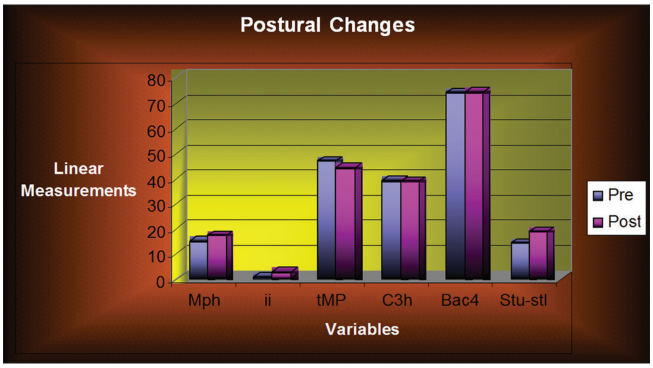
The hyoid bone, follows mandibular movement ($r = -0.71$, $P < 0.009$). and increased cranial extension is associated with greater opening in hyoid plane angle ($r = -0.44$, $P < 0.027$). A lowering in tongue position (t-MP) is partially associated with a drop in hyoid position (h-MP) ($r = -0.71$, $P < 0.001$) and drop in the tongue position is associated with lowering of mandible ($r = -0.41$, $P < 0.043$). A decreased change in cervical lordosis is weakly associated with an increased change in craniocervical extension ($r = -0.47$, $P < 0.016$).

Graphs 1 and 2 show the comparison between the pre-nasal and post-nasal blockage values of linear and angular measurements, respectively.

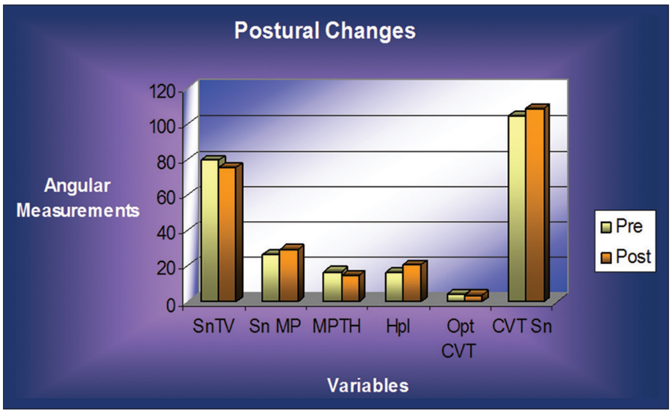
Discussion

Nasal respiratory obstruction has been considered an important key to morphogenesis of the nasomaxillary complex. It is commonly assumed that naso-respiratory function can exert a dramatic effect on the development of the dentofacial complex. Specifically, it has been stated that chronic nasal obstruction leads to mouth breathing, which causes altered tongue, cranium, hyoid, and mandibular positions.

Both in the orthodontic and anthropologic literature, NHP have been proposed as a postural basis for craniofacial



Graph 1: Comparison between the pre-nasal and post-nasal blockage values (linear measurements).



Graph 2: Comparison between the pre-nasal and post-nasal blockage values (angular measurements).

Table 4: Statistically significant correlations between postural adaptations.

Variables	SN-MP	MP-TH	h pl ang	OPT-CVT	Cvt-Sn	MPh	i - i	tMP	C3h	Bac4	Stu-Stl
SN-TV	−0.006 0.98	0.52 0.007 HS	−0.44 0.03 S	−0.45 0.02 S	−0.48 0.015 S	−0.27 0.196	0.45 0.02	0.25 0.24	−0.12 0.57	−0.14 0.50	0.20 0.25
SN-MP		0.47 0.02 S	−0.072 0.73	0.322 0.116	0.48 0.02 S	0.37 0.07	0.48 0.82	−0.40 0.05 S	0.26 0.20	0.29 0.17	0.26 0.21
MP-TH			−0.31 0.13	−0.23 0.28	−0.02 0.93	0.27 0.19	0.15 0.47	−0.40 0.04 S	0.27 0.18	0.11 0.61	0.54 0.80
h pl ang				0.27 0.21	−0.012 0.96	0.51 0.009 HS	0.11 0.60	−0.014 0.50	0.35 0.90	0.05 0.81	0.52 0.80
OPT-CVT					0.48 0.02	0.26 0.21	0.17 0.41	0.19 0.34	0.04 0.87	0.01 0.96	0.29 0.15
CVT-SN						0.22 0.29	0.22 0.28	0.33 0.10	0.17 0.42	0.27 0.19	0.15 0.46
MP-h							0.02 0.91	−0.71 0.001 VHS	0.17 0.41	0.17 0.43	0.09 0.66
i-i								0.01 0.97	0.240 0.25	0.19 0.87	0.01 0.12
t-MP									0.05 0.82	0.04 0.87	0.09 0.97
C3-h										0.17 0.40	0.13 0.52
Ba-C4											0.34 0.09

OPT: Odontoid process tangent, CVT: Cervical vertebral tangent, SN: Sella-nasion, TV: True vertical, MP: Mandibular plane, TH: True horizontal, HS: Highly significant, VHS: Very highly significant, S: Significant

morphologic analysis. Several investigators have demonstrated a relationship between NHP and craniofacial morphology. Based on the findings that individual variance of NHP is significantly smaller than the interindividual variability of the classic intracranial reference planes, it has been recommended that NHP be used for cephalometricanalysis.[13,14]

It was clear that there is a pattern of association between NHP and certain craniofacial characteristics. Facial axis, lower face height, and the facial ratio are the morphologic variables more often associated with NHP. Recent study[15] has concluded that airway dimension and tongue- and hyoid-position measurements are highly reproducible on natural-head-position cephalograms.

Essentially, two different methods for recording an NHP are described in the publications.[16,17] One is the "mirror position" in which a subject looks in a mirror into his own eyes, the other is the "self-balance position" that establishes the head orientation based on the subject's proprioceptive input. Although the mirror position has better reproducibility,[13] it has the disadvantage that it may not be the position habitually used by the subject outside the experimental situation. In addition, both methods have been proven to be between the limits of sufficient reproducibility and to lead to similar associations between postural and craniofacial variables.[18] For these reasons, we gave preference to the self-balance position. Cephalometric head holder was not used in some studies because the ear rods can influence the NHP and lead to an increased method error for the postural variables.[19] However, some studies[16] have shown no significant differences in reproducibility were detected between NHP recordings taken with and without ear posts. However, without ear posts the radiographs tended to be of poor quality. To avoid any pitfalls we positioned subjects in the cephalostat according to the previously determined head position. To avoid spoiling the established position, the rods were not inserted into the acoustic meatus but reversed to support the head from both sides by lightly touching the ears.[15]

Significant controversy exists in the orthodontic publications concerning the validity of different methods used to assess a person's mode of breathing.[7] Although it has not been proven quantitatively in this study, the fact that all subjects were able to breathe effortlessly through their nose with their lips contacting for an extended period of time is good clinical proof of a nasal breathing pattern during that observation period. To eliminate any doubt about the oronasal percentage ratio of the airflow, the nasal passages were totally blocked during the experiment.

Because the structures lying above the level of the palate are largely fixed, compensatory functional respiratory adaptations will occur at the level of the oropharynx.[20] Several descriptions of those postural reflexes have previously been based on clinical observations, without an attempt to objectively measure oronasal respiratory ratio and without quantification of the postural changes.[21] Moreover, cross-sectional studies that found significant correlations between postural variables and degree of nasal resistance[13] cannot, by their nature, show any cause and effect relationship. In longitudinal post adenoidectomy studies,[22] the contraction of scar tissue and altered oral sensation may influence head posture. This study has attempted to avoid those pitfalls by its experimental design as described previously.

By virtue of its muscular and ligamentous attachments, several authors have reported difficulty in the reproducibility of hyoid position.[23,24] Significant interpersonal variations in position have also been noticed. In contrast, a relative constancy of intraindividual hyoid position throughout growth periods has been described,[25] along with a relatively constant anteroposterior diameter of the pharynx at this level. Nevertheless, this tendency toward positional hyoid instability should be taken into account with the interpretation of the data. In addition, a lateral cephalogram can only give a momentary picture of the dynamic reflexive adaptation process and is not necessarily representative of that patient's behavior. This may explain why in some persons actual decreases in mandibular opening and lip separation were noted (Table 3).

The hyoid bone serves an essential role in respiratory function. Brodie *et al*.[20] demonstrated that the contraction of hyoid muscles in response to chemical, vagal, and negative pressure stimuli reduced upper airway resistance.

Several postural adaptation mechanisms previously described in the clinical studies were noted in this sample. Parting of the lips with mandibular opening and an increase in freeway space were the most significant findings and it corroborates the reports of Subtelny[21] and Bowen and Balyeat.[26] The lowering of the hyoid position also found in this study has been described previously[27] as a mechanism to preserve airway patency. Tongue pressure along with position is considered to be a particularly important factor in the diagnosis and prognosis of orthodontic treatment. Archer and Vig *et al*.[9] reported that the tongue pressure on the lingual surface of the mandibular incisors tended to decrease with head extension and to increase with head flexion in subjects with Class I malocclusions but recent studies, Song HG,[28] have shown that tongue pressure showed respiratory-related cyclic oscillations, with a maximum value during expiration and a minimum value during inspiration. The maximum tongue pressure during oral breathing was significantly greater than during nasal breathing.

The reflexive behavior of the hyoid bone was significantly correlated with tongue position ($r = -0.71$, $P < 0.001$). This reciprocally positional relationship has been described by Brodie.[29] The hyoid bone, follows mandibular movement ($r = -0.71$, $P < 0.009$) and increased cranial extension is associated with greater opening in hyoid plane angle ($r = -0.44$, $P < 0.027$), as seen in the study.[30] A lowering in tongue position (t-MP) is partially associated with a drop in hyoid position (h-MP) ($r = -0.71$, $P < 0.001$) As expected, statistically significant differences were found for head extension (SN-TV) and craniocervical extension (CVT-SN) ($P < 0.001$). Head extension is associated with craniocervical extension ($r = 0.48$, $P < 0.015$).

No significant difference in cervical lordosis (opt-cvt) was found, but when it occurs, it may indirectly help airway patency because weak correlations were shown between a decreased change in lordosis and an increased distance between the cervical spine and the hyoid bone ($r = -0.46$, $P < 0.05$). A decreased change in cervical lordosis is weakly associated with an increased change in craniocervical extension ($r = 0.47$, $P < 0.02$). Typically, described is an association between decreased lordosis and increased craniocervical extension.[18] However, this association may be found within certain craniofacial morphologic subgroups,[18] as they have not been concomitantly described as postural airway reflexes.[31]

Harvold *et al*.[32] and Miller *et al*.[33] described the early postural adaptations of primates adapting to complete nasal blockage. The animals showed continuous or rhythmic lowering of the mandible. Their tongue and lips altered shape in a variety of configurations, along with a rhythmic or continuous change in position. Electromyographic (EMG) changes in dorsal tongue fibers, suprahyoid, genioglossus, and orbicularis oris muscles were found.[33] Because the animals coped in different ways with nasal obstruction, the dento-alveolar distortions were not uniform and different types of malocclusions resulted.[32] However, the skeletal changes noticeable after 1 year of nasal obstruction were uniform in that all animals showed an increase in facial height, MP angle and gonial angle.[32]

The same dramatic craniofacial and oral muscle behavioral change was not noticed in the human experimental group. The reason for this may be the anatomic difference between the human and the primate oropharyngeal anatomy.[33] An oral airway passage is structurally easier accomplished and less life threatening in the human being, obviating the need for excessive muscle recruitment.[34] As such, human adaptation to oral respiration requires only a small adjustment in a mandibular position to maintain a patent oral respiratory tract. Nasal obstruction in human subjects leads to a decrease in post-cervical and anterior temporal muscle tone and only to a weakly significant and very temporary increase in suprahyoid muscle EMG activity.[10] This and the observed individual variations in response may explain why clinical longitudinal studies did not show the same dramatic and consistent impact on the craniofacial growth pattern.[35]

Conclusion

The present study concludes that there was definite postural adaptation like significant opening of the lips, a mandibular postural adaptation with a downward and backward rotation, increased mouth opening, significant drop in tongue position, vertical drop in hyoid position, and extension of the head with craniocervical extension to facilitate oral respiration due to total nasal obstruction.

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