Relationship of the functional oropharynx to craniofacial morphology

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Abstract: The association between the functional oropharyngeal airway (defined as the minimal sagittal dimension at right angles to the airstream) and craniofacial morphology was investigated using 16 craniofacial variables taken from lateral cephalometric radiographs. The sample consisted of 70 subjects (31 males and 39 females) 10 to 13 years of age. There was no difference in ages between males and females, and no correlation with age except upper face height. Oropharyngeal airway was positively correlated with length of the mandible (Gon-Men), the distance between the third cervical vertebra and the hyoid bone (C_3-Hy), and cranial base angle (NSBa). Although short mandibular length is a characteristic finding in patients with obstructive sleep apnea, none of the subjects in this study had this diagnosis.

Key Words: Functional oropharyngeal airway, Craniofacial morphology, Lateral cephalometric radiograph

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The oropharyngeal airway (OPA) is bound by the glottic aperture below and leads into the nasopharyngeal airway above. This portion of the upper airway has attracted less attention than its nasal counterpart, yet it, too, plays a role in the passage of respiratory gases to and from the lungs. The efficiency of this gaseous transfer depends largely upon the airway size, but this has been studied very little with reference to facial morphology. Pierre Robin, an early worker in this area, is best remembered for the cleft palate syndrome with glossoptosis that bears his name. He believed that a retrognathic mandible held the tongue back, thus restricting the respiratory airflow and leading to pathologic sequelae. Robin[1] designed the monobloc appliance, which repositioned the mandible and tongue anteriorly to enlarge the airway. This approach is experiencing a revival in the treatment of snoring and obstructive sleep apnea syndrome (OSAS),[2,3,4] especially as a retrognathic mandible is often implicated.[5,6]

Recent advances in imaging and a variety of other investigative techniques have stimulated a spate of reports on the OPA, in particular: computerized tomography,[7-10] acoustic reflection,[11-14] flouroscopy,[15,16] fibro-optics,[17] and magnetic resonance.[18,19] Despite these sophisticated methods, the lateral cephalometric radiograph is still commonly used in examining the OPA and other anatomic features.[2,16,20-23] However, in the majority of these citations, the OPA was quantified by taking a line joining two skeletal points and measuring the distance between marks where the line crossed the posterior and anterior walls. The functional efficiency of the OPA, according to its conductance of respiratory gases, is dictated largely by its narrowest part, and the best measurement would be the cross-sectional area at right angles to the airstream. For the purposes of this study, the minimal linear distance between the back of the tongue and posterior pharyngeal wall was taken as a fair representation of this space. This dimension was then used to compute correlations with certain conventional angles and lengths in order to assess its relationship to the craniofacial skeleton.

Materials and methods

This study was based on the cephalometric radiographs of patients referred to the Royal Preston Hospital Orthodontic Clinic for advice or treatment. The radiographs were pulled en bloc and in sequence to avoid bias. Cases were

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rejected for: cleft lip and/or palate (abnormality), non-Caucasian (heterogeneity), Frankfort horizontal more than 10 degrees above true horizontal (head extension increases the OPA[22]), poor resolution of reference points, or age outside the 10- to 13-year range.

The sample consisted of 70 subjects, 31 males and 39 females, who were between 10 and 13 years old (mean age 11.75 years, Table 1). The age range was restricted to minimize the effect of growth on craniofacial dimensions. This is because associations between variables and OPA may well be due to a common dependence on age, rather than a true relationship.

The cephalometric radiographs were taken on a standard Siemens cephalostat at a distance of 2 meters, with the subject upright, Frankfort plane in true horizontal, and teeth in centric occlusion.

Acoustic reflection has shown the size of the OPA to vary slightly between total lung capacity and residual volume in the ratio of 4:3.[12] All subjects received the same instructions for radiographic exposure in order to place the tongue in a relaxed position relative to the facial structures. Cephalograms were taken with the Frankfort plane horizontal, rather than the natural head position,[24] as a variable head position leads to a variable OPA dimension.[22] The landmarks have been shown to be reliable on a single cephalogram.[25]

The radiographic enlargement was indicated by a millimeter scale incorporated in the machine. Tracings were made by the same person (DJT) using a sharp pencil on acetate paper over an illuminated opal light box. Certain conventional anatomic points were marked. These were joined to give 6 angular and 10 linear variables (Figure 1), which, in view of the inherent errors in cephalometric mensuration,[26,27] were measured to the nearest half degree and half millimeter. The following variables were recorded (Table 1).

Table 1
Cephalometric variables

	Mean	SD	SE
Age	11.75	1.30	0.16
OPA	8.95	2.46	0.29
NSBa <	129.74	4.92	0.59
Max Man <	26.96	6.03	0.72
ANB <	2.54	3.30	0.40
SNA <	79.22	3.78	0.45
SNB <	76.69	3.67	0.44
Gonial <	127.66	7.20	0.86
N-S	71.77	3.51	0.42
N-Ba	109.01	4.81	0.57
Man-Hy	14.04	5.92	0.71
C_3-Hy	32.06	3.94	0.47
Gon-Men	69.34	4.42	0.53
AFH (U)	51.73	3.42	0.41
AFH (L)	62.17	5.56	0.66
PFH (U)	42.35	7.21	0.86
PFH(L)	30.01	4.37	0.52
Ba-A	93.49	6.04	0.72

Table 2
Correlation of variables with age

	r	p
OPA	0.0002	NS
NSBa <	0.052	NS
Max Man <	-0.034	NS
ANB <	0.164	NS
SNA <	0.139	NS
SNB <	-0.004	NS
Gonial<	0.031	NS
NS	0.168	NA
N-Ba	0.200	NS
Man-Hy	0.215	NS
C_3-Hy	0.103	NS
Gon-Men	0.166	NS
AFH (U)	0.339	0.005
AFH (L)	0.155	NS
PFH (U)	0.231	0.05
PFH (L)	0.180	NS
Ba-a	0.175	NS

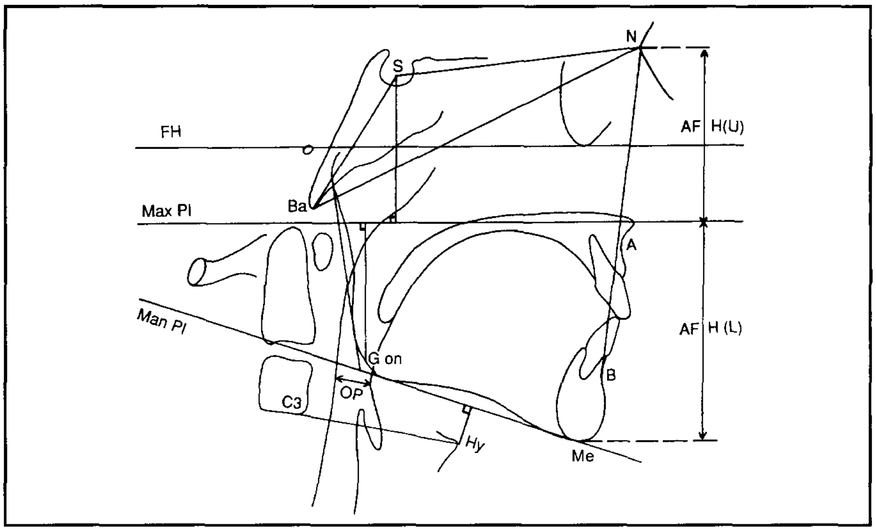

Figure 1
Schematic lateral cephalogram showing reference points and planes

Angular variables
- (i) Nasion–sella-basion
- (ii) Maxilla (ANS-PNS)–Mandibular (Go-Me) planes
- (iii) Sella–nasion–A-point
- (iv) Sella–Nasion–B-point
- (v) A-point–nasion–B-point
- (vi) Gonial angle (between mandibular and posterior ramus planes)

Linear variables
- (i) Nasion–sella
- (ii) Nasion–basion
- (iii) Mandibular plane (Go-Me)–hyoid bone (anterosuperior corner)
- (iv) Third cervical vertebra (anteroinferior corner)–hyoid bone (anterosuperior corner)
- (v) Gonion–menton
- (vi) Upper anterior face height (N–max plane)

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(vii) Lower anterior face height (Me–max plane)
(viii) Upper posterior face height (S–max plane)
(ix) Lower posterior face height (Go–max plane)
(x) Basion–A-point

The OPA was measured as the minimal sagittal linear distance between the back of the tongue and the posterior pharyngeal wall. This was at right angles to the airstream, approximately horizontal, between the uvula and epiglottis. The OPA was correlated with age (Table 2) and cephalometric variables (Table 3) using correlation coefficients (r). The cases were divided into males and females, and the data were compared using a student's *t*-test to see if there was any difference between sexes (Table 4). The method error (ME) was determined by random selection of 1 in 10 radiographs for retracing and remeasuring them. The calculation used the formula:

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where d = difference between measured pairs and n = number of pairs. The error variance was then compared with the biologic variance of the total material and expressed as a percentage (Table 5). The ME was comparable to other cephalometric studies and less than 10% of the biologic variance.

Table 3
Correlation of variables with OPA

	r	p
Age	0.0002	NS
NSBa <	0.262	0.05
Max Man <	-0.195	NS
ANB <	-0.086	NS
SNA <	0.006	NS
SNB <	0.086	NS
Gonial <	-0.163	NS
N-S	0.034	NS
N-Ba	0.157	NS
Man-Hy	0.038	NS
C_3-Hy	0.298	0.01
Gon-Men	0.290	0.01
AFH (U)	0.090	NS
AFH (L)	-0.055	NS
PFH (U)	0.125	NS
PFH (L)	0.005	NS
Ba-A	0.159	NS

Table 4
Difference between males and females

	t	p
Age	0.05	NS
OPA	0.39	NS
NSBa <	1.31	NS
Max Man <	1.91	NS
ANB <	1.63	NS
SNA <	0.02	NS
SNB <	1.49	NS
Gonial <	0.69	NS
N-S	1.79	NS
N-Ba	1.57	NS
Man-Hy	0.19	NS
C_3-Hy	1.51	NS
Gon-Men	0.45	NS
AFH (U)	1.09	NS
AFH (L)	1.80	NS
PFH (U)	1.41	NS
PFH (L)	1.02	NS
Ba-A	0.66	NS

Table 5
Experimental error

Variable	Method error	Error variance	Sample mean	Standard deviation	Total deviation	Error variance % total variance
OPA	0.443	0.196	8.95	2.46	6.05	3.24
NSBa <	1.150	1.323	129.74	4.92	24.21	5.46
Max-Man <	1.170	1.376	26.96	6.03	36.36	3.78
ANB <	0.463	0.214	2.54	3.30	10.89	1.97
SNA <	0.835	0.697	79.22	3.78	14.29	4.88
SNB <	0.926	0.858	79.69	3.67	13.47	6.37
Gonial <	1.254	1.573	127.66	7.20	51.84	3.03
N-S	0.509	0.259	71.77	3.51	12.32	2.10
N-Ba	1.094	1.197	109.01	4.81	23.14	5.17
Man-Hy	0.779	0.607	14.04	5.92	35.05	1.73
C_3-Hy	0.648	0.420	32.06	3.94	15.52	2.71
Gon-Men	1.114	1.241	69.34	4.42	19.54	6.35
AFH (U)	0.845	0.714	51.73	3.42	11.70	6.10
AFH (L)	0.535	0.286	62.17	5.56	30.91	0.93
PFH (U)	1.070	1.145	42.35	7.21	51.84	2.21
PFH (L)	1.206	1.454	30.01	4.37	19.10	7.61
Ba-A	0.973	0.947	93.49	6.04	36.48	2.60

Results

Because correlation with OPA may be due to the common dependence on age, it is important to eliminate this factor. For this reason, the cephalometric measurements were correlated with age (Table 2). With the exception of AFH (U) and PFH (U) none of the cephalometric variables showed any statistically significant correlation with age. This eliminates age as a factor responsible for any correlations with OPA other than upper anterior and posterior face height, which in fact did not correlate with OPA.

The cephalometric parameters were then correlated with OPA (Table 3). Three of 16 variables showed moderate correlation that was statistically significant. The cranial base angle (NSBa), the distance between the third cervical vertebra and the hyoid bone (C_3-Hy), and mandibular length (Gon-Men) all showed positive correlation with OPA.

To find any differences between the sexes, the data were divided into male and female groups and a student's *t*-test was performed (Table 4). There was no significant difference between males and females, hence the data were combined.

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Discussion

The cases were drawn from patients with malocclusions; consequently, the sample might not be entirely representative of the population as a whole and some bias should be assumed. However, the cephalometric measurements compared favorably with a randomly selected sample of schoolchildren in Manchester,[28] a town 30 miles away and the nearest available source of a community standard.

Because the facial skeleton generally increases in size with growth, associations between cephalometric variables are usually due to common dependence on age. In the present study, the effect of age was minimized by restricting the age range to 10 to 13 years and testing for correlation with age. None of the cephalometric parameters that correlated significantly with OPA showed any correlation with age. Thus, there must be a true relationship between OPA and the cranial base angle (NSBa), the distance between the third cervical vertebra and the hyoid bone (C_3-Hy) and mandibular length (Gon–Men). The relationship between OPA and the distance between the third cervical vertebra and the hyoid bone (C_3–Hy) and mandibular length (Gon-Men) would appear logical, because as the body of the mandible lengthens, the attachments of the genioglossus and geniohyoid muscles move forward away from the oropharynx, increasing the OPA. The OPA also increases as the cranial base angle (NSBa) opens up. This could be explained as a more posterior positioning of the temporomandibular joint, requiring a longer mandible to maintain a normal relationship with the maxilla, so increasing the OPA.

Although this study was not directly concerned with sleep disorders, there were findings associated with OSAS, the most important being the direct relationship of the OPA to mandibular length (Go–Me) because short mandibular length was also a prime finding in a number of OSAS reports.[29,30,31]

While the present study strongly supports an association between a short mandible and small OPA in the context of OSAS, the same could not be said for the relationship of the OPA to long-face syndrome, where a reduced OPA did not correlate with an increased maxillary / mandibular plane angle and increased anterior face height. Comparison with other work on this topic is difficult due to a paucity of morphologic studies using the minimal postlingual dimension as a parameter. Fricke et al.[23] used it in connection with lip competence, and Battagel et al.[16] in assessments with mandibular advancements for antisnoring splints. Özbek et al.[32] also used this OPA measurement and found that it increased in patients after successful treatment with functional appliances.

Conclusions

Oropharyngeal airway size was positively correlated with (1) the length of the mandible (Gon–Men), (2) the distance between the third cervical vertebra and the hyoid bone (C_3-Hy), and (3) the cranial base angle (NSBa).

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