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THE RELATIONSHIP BETWEEN CRANIOFACIAL CHARACTERISTICS and OROPHARYNGEAL SPACE

İREM SOYDAŞ
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SUPERVISOR
Assoc. Prof. Dr. Banu ÇAKIRER

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Supervisor (Title, Name, Surname)	**Institution**	**Signature**
Assoc. Prof. Banu ÇAKIRER	M.U. Institute of Health Sciences	
Members of Examination Jury (Title, Name, Surname)		
Prof. Dr. Nazan KÜÇÜKKELEŞ	M.U. Institute of Health Sciences	
Prof. Dr. Ahu ACAR	M.U. Institute of Health Sciences	
Assoc. Prof. Dr. Çağlar ÇUHADAROĞLU	İ.U. Institute of Health Sciences	
Assoc. Prof.. Dr. Toros ALCAN	M.U. Institute of Health Sciences	

The above examining jury decision have been approved by Institute of administrative board decision with ..30.:.06..2009.dated and .....11........ numbered.

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Director of Institute of Health Sciences

Prof. Dr. Nimet GENÇOĞLU
Müdür

DECLARATION

I declare that this thesis is a result of my own studies, from the beginning to the end at every stage and there is no non-ethical act. All the information in this thesis is acquired in the borders of academical and ethical rules. The information and the comments mentioned that are not a part of my own study are referred and all the references are have a part in the reference list. During the study and writing of this thesis I did not have any prohibiting act on patent and copyright laws.

24/06/2009
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V. Abbreviations and Symbols

1. et al. : And friends
2. mm. : Millimeters
3. p : Probability
4. % : Percent

1. SUMMARY

A mutual interaction is expected to occur between the pharyngeal structures and the dentofacial pattern because of the close relationship between the pharyngeal and both dentofacial and craniofacial structures. The aim of this study is to investigate the association between the upper airway and craniofacial morphology by using craniofacial variables taken from lateral cephalometric radiographs. This study is based on the initial lateral cephalometric radiographs of 250 subjects (100 males and 150 females), of 16 to 19 years of age, selected from the archieves of patients who were treated at the Marmara University Faculty of Dentistry Department of Orthodontics. The association between the oropharyngeal airway and craniofacial morphology was investigated by using 16 craniofacial variables taken from lateral cephalometric radiographs. Anatomic landmarks and reference planes were traced manually, using conventional methods. Measurements were performed by using AutoCAD R 17.2 software (AutoDesk Co, 2009, USA) to measure the oropharyngeal area, and other distances digitally. In order to eliminate the effect of head posture on the pharyngeal airway space, first, measured variables related with upper airway dimensions were corrected with the use of appropriate regression equations as suggested in the previous literature (84, 85), and second, the cephalograms with a Frankfort horizontal plane 10° above the true horizontal plane were excluded. Evaluation of the study results showed that the oropharyngeal airway distances and area were positively correlated with the length of mandible. The nasopharyngeal airway (ad1) was in positive correlation with the sagittal maxillary position. The craniocervical inclination was only associated with the nasopharyngeal airway (ad1). PAS-UP (posterior pharyngeal wall-soft palate distance) distance was positively correlated with 3rd cervical vertebrae and hyoid bone. Corrected PAS-UP and Corrected PAS-TP(posterior pharyngeal wall-base of the tongue) values were in correlation with high angle skeletal growth pattern, emphasizing larger pharyngeal airways.

Keywords: Craniocervical inclination, Craniofacial morphology, Head posture, Lateral cephalometric radiograph, Pharyngeal airway space

2. ÖZET

Kraniyofasiyal Özellikler ve Orofarengeal Boşluk Arasındaki İlişkinin Sefalometrik Olarak İncelenmesi

Farengeal yapının, dentofasiyal ve kraniyofasiyal yapılar ile olan yakın ilişkisinden dolayı, dentofasiyal modelin hava yoluna ait yapıları etkilemesi beklenir. Bu çalışmanın amacı, lateral sefalometrik röntgenler üzerinde ölçülen kraniyofasiyal değişkenleri kullanarak, üst havayolu ve kraniyofasiyal morfoloji arasındaki ilişkiyi araştırmaktır. Bu çalışmada, M.Ü. Diş Hekimliği Fakültesi Ortodonti Anabilim Dalı'na tedavi olmak için başvurmuş, yaşları 16 ile 19 arasında olan, 250 hastanın (100 erkek ve 150 kız) arşivde bulunan tedavi oncesi lateral sefalometrik röntgenleri kullanılmıştır. Üst havayolu ve kraniyofasiyal morfoloji arasındaki ilişki, lateral sefalometrik röntgenler üzerinde işaretlenen 16 adet kraniyofasiyal değişken kullanılarak araştırılmıştır. Orofarengeal alan ve diğer değerler, dijital olarak AutoCAD R 17.2 yazılımı (AutoDesk Co, 2009, USA) kullanılarak ölçülmüştür. Baş pozisyonunun havayolu üzerinde oluşturduğu etkiyi yok etmek için, ilk olarak; daha önceki çalışmalarda (84, 85) önerildiği şekilde, ölçümü yapılan havayolu parametreleri uygun regresyon katsayıları kullanılarak düzeltilmiş, ikinci olarak ise; Frankfort Horizontal düzlemi ile yer düzlemi arasındaki açının 10°'den daha yüksek olduğu belirlenen röntgenler çalışmaya dahil edilmemiştir. Çalışma bulguları değerlendirildiğinde; orofarengeal havayolu genişliği ve alanının, alt çene uzunluğu ile, nazofarengeal havayolunun ise üst çenenin ön arka düzlem üzerindeki pozisyonu ile pozitif korelasyon gösterdiği görülmüştür. Kraniyofasiyal açının sadece nazofarengeal havayolu ile ilişkide olduğu gözlenmiştir. PAS-UP (posterior farengeal duvar-yumuşak damak) mesafesi 3. servikal vertebra ve hyoid kemiği ile ilşkidedir Yüksek iskeletsel büyüme paternine sahip bireyler, Corrected PAS-UP ve Corrected PAS-TP (posterior farengeal duvar-dil kökü mesafesi) değerleri ile pozitif korelasyon göstermektedir.

Anahtar Kelimeler: Kraniyoservikal açı, Kraniyofasiyal morfoloji, Baş pozisyonu, Lateral sefalometrik röntgen, Farengeal havayolu boşluğu.

3. INTRODUCTION and AIM

Among the predisposing factors for obstruction of the pharyngeal airways such as allergies, environmental irritants, and infections, which are amenable to adequate treatment there is also the natural anatomical predisposition of narrower airway passages (21, 70, 122). Because of the close relationship between the pharynx and the dentofacial structures, a mutual interaction is expected to occur between the pharyngeal structures and the dentofacial pattern, and therefore justifies orthodontic interest. In many studies, it has been demonstrated that there are statistically significant relationships between the pharyngeal structures and both dentofacial and craniofacial structures at varying degrees (29, 60, 78, 80, 110).

Differences in the size and the shape of the cranium and cranial base actually form the anatomic basis for subsequent variations in facial and upper airway morphology (36). In the classification of human head form, the two extremes are brachycephaly and dolichocephaly types. Brachycephalic head forms are wider in the biparietal dimension and shorter in the anterior-posterior dimension. This head form is associated with a cranial base that is wider and shorter. Because the face is built on the cranial base, brachycephalic persons usually have wider and shorter (euryprosopic) facial forms. Dolichocephalic subjects exhibit a narrower biparietal width and relatively longer anterior-posterior length resulting in a cranial base that is also narrower and longer and a long-thin (leptoprosopic) facial form (36). Moreover, the cranial base forms the template for the airway, as well as the face. Thus, the dimensional, angular, and topographic characteristics of these structures vary according to head form type. In particular, the skeletal dimension of the pharynx is established by the size of the middle cranial fossa-the area between the dorsum sellae and the center of the anterior border of the foramen magnum. The floor of this baso-cranial fossa is the roof of the pharyngeal compartment. A brachycephalic head form results in shorter anterior-posterior dimensions of the cranial base, greater cranial base flexure, reduced middle cranial fossa, and reduced upper airway anterior-posterior dimension (36, 120). Since the middle cranial fossa is shorter in these subjects, it has been hypothesized that they should have greater anatomic risk of airway collapse. Consistent results with this hypothesis have been published (7, 17, 72, 76, 109, 121).

Although brachycephalic patients were found to be more prone to pharyngeal constriction, it has been reported that patients with vertical growth patterns had significantly narrower upper pharyngeal airways than subjects with normal growth pattern (1, 29).

The Cranial base angle is relatively stable but shows large individual variations. Since the cranial base consists of two segments articulating with the maxilla and the mandible, respectively, any changes in flexure due to variations in shape and size of this region may alter the anteroposterior skeletal relationship of the jaws, thus influencing the type of malocclusion and the pharyngeal airway space (96).

Cranial base angle (CBA) is one of the many factors which are involved in the determination of the nasopharyngeal airway patency. In the long face syndrome nasopharyngeal depth is significantly short whereas it is longer in the small face syndrome, in which the CBA is larger in the former (38, 89). The CBA of persons with dolichocephalic growth patterns is reported to have a tendency for an obtuse angle (34). Consequently, the nasopharyngeal depth is expected to be increased contributing for an increased airway patency. Contrary to this, most studies reveal that CBA does not have much effect on vertical development of the face than commonly presumed (32).

Growth and development of the pharynx have been studied longitudinally by different investigators, as has the relationship between airway patency and craniofacial development (41, 44, 66, 70). This interest has been derived from a potential relationship between size and structure of the upper airway and the craniofacial morphology. But there have been studies presenting that insignificant changes occur in the airway patency related to the changes in the craniofacial development. In addition, a relationship between nasopharyngeal area and a dental Class I or II occlusion is either nonexistent or very weak (45, 60, 114).

The literature has still controversy about this issue, therefore by taking the effects of head posture on the pharyngeal airway space into consideration, we aimed to investigate the association between the upper airway and craniofacial morphology on lateral cephalometric radiographs.

4. LITERATURE REVIEW

4.1. Growth of The Cranial Base and Facial Structures Related with Upper Airway

Growth is a process requiring intimate morphogenic interrelationships among all of its component growing, changing, and functioning soft and hard tissue parts. No part is developmentally independent and self contained. The growth process works toward an ongoing state of composite functional and structural equilibrium (36).

Intra-uterine growth of the cranial base is highly uneven. It develops an irregular shape to accommodate the undulating surface of the growing brain. The anterior and posterior parts of the midline cranial base, divided at sella turcica, are known to grow at different rates. Between the 10th to 40th weeks i.u, the anterior cranial base (ACB) increases in length and width sevenfold while the posterior cranial base (PCB) increases only fivefold (115). Pre-natally, the sphenooccipital synchondrosis (SOS) does not contribute to growth as much as it does post-natally. Growth of the cranial base initially takes place as a result of growth at the synchondrosis, and expansive forces originating from the growing brain that displace the bones at the suture lines. Specifically, the sutures involved in anterior- posterior growth of the ACB are the spheno-frontal, fronto-ethmoidal, and the spheno-ethmoidal. Many sutures fuse at the time of birth or slightly thereafter, but the latter two continue to grow after birth. Although the spheno-ethmoidal suture is known to persist until adolescence, desmolytic degeneration of the cartilage produces a suture that is of minimal significance in postnatal growth (115).

The central region of the cranial base is composed of pre-chordal and chordal parts which meet at an angle at the sella turcica. In the sagittal plane, these parts form an angle which is often referred to as the "Cranial base angle" or N-S-Ba. In the 4 week old embryo, this angle is initially obtuse (150 degrees). The angle flexes to about 130 degrees in the 7-8 week old embryo, and becomes even more acute at 10 weeks (120 degrees). As the head starts to raise, and the cranial base begins to ossify, there is slight opening of the angle back up to 130 degrees. This angle is fairly stable post-natally. Flattening of the Cranial base angle is thought to be caused by rapid brain growth in the fetal period, as the chondrocranium mains its original obtuse angle in cases of anencephaly (115).

Development of the face occurs primarily between the 4th and 8th weeks. Facial development occurs slowly and results from changes in the proportions and positions of the facial components (83).

The mandible is the first pair of the face to form. It results from merging of the medial ends of the two mandibular prominences in the median plane in the 4th week. By the end of the 4th week, thickenings of the surface ectoderm have developed. Mesenchyme proliferates in these thickenings and forms the medial and lateral nasal prominences. The centers, or pits of these elevations are the primordia of the nostrils and nasal cavities. The maxillary prominences proliferate and grow medially towards each other and the nasal prominences. By the end of the 6th week, each maxillary prominence has begun to merge with the lateral nasal prominence. Between the 7th and 10th weeks, the medial nasal prominences merge with each other and the maxillary and lateral nasal prominences, resulting in continuity of the upper jaw and lip.

The bones of the cranial base are initially formed in cartilage and are transformed into bone through the process of endochondral ossification. In terms of post-natal growth, the most important synchondroses to persist are the spheno-ethmoidal synchondrosis (SES) and SOS. Growth at the SES is said to be responsible for ACB growth. Initially, the SES growth proceeds at a faster rate than the SOS, but there is negligible activity after age seven. The SOS however, does not fuse until adolescence and is the main contributor to PCB growth. This prolonged growth provides space for the growing nasopharynx and for continued maxillary lengthening to allow for the molars to erupt (115). Coben (24) holds the opinion that the SOS is the "missing link" in craniofacial growth. He claims that growth at the SOS translates the ACB and its attached upper face upwards forwards, away from the foramen magnum and the vertebral column. In addition to proliferative synchondrosal growth, the cranial base undergoes selective remodeling by resorption and deposition. By this method, growth continues even after the synchondroses fuse.

The major interrelated form/function components involved in development are the brain with its associated sensory organs and basicranium, the facial and pharyngeal airway, and the oral complex. They are developmentally inseparable. The configuration of the neurocranium (and brain) determines the headform type which in turn sets up many of the proportionate and topographic features characterizing facial type. There are two basic extremes in the shape of the head. The first type is an oval dolichocephalic form that is horizontally long and relatively narrow and that is associated with a face that is also narrow and long (leptoprosopic) with a more frequent built-in tendency for mandibular retrusion. The second type is the brachycephalic head form, which is horizontally shorter and broader and typically characterized by a facial type with the same characteristics (short and broad, euryprosopic) with generally underlying a more orthognathic (or less retrognathic) profile, or in the extreme, a tendency for mandibular or bimaxillary protrusion. Those persons with dolichocephalic growth patterns are traditionally reported to have a tendency toward an obtuse Cranial base angle (CBA) (34, 104). Remarkably enough, this would seem to have the consequence of increasing the depth of the nasopharynx, which would be more pronounced than normal, and would contribute to a structural basis for an increased patency of the airway in these persons. However, contrary to this belief, most studies reveal that the cranial base in the long face syndrome (LFS), which is characterized by a constellation of clinical features indicative of extreme vertical growth, is essentially normal (32). In other words, the CBA seems to have less influence on the vertical development of the face than commonly presumed.

Even so, the CBA is not the only factor involved in the determination of the patency of the bony nasopharynx. Nasopharyngeal depth (the distance of PNS to the posterior pharyngeal wall) is significantly shorter in the LFS than in the small face syndrome (SFS), which is characterized by extreme euryprosopy, even though the CBA is larger in the former. This would be due to a retrognathic position of the whole maxilla relative to the SN: The PNS and the anterior nasal spine (ANS) are in more distal positions, whereas the SNA angle remains unchanged (32, 38, 89). The hyoid bone is also displaced more closely to the cervical spine in the LFS. Together with an increased mandibular plane angle (SN-GoGn) and an increased SN-hyoid plane angle, the cervical spine rotates backward and up against the cranial base. The overall rotation of these skeletal structures has been interpreted as a mechanism to restore the pharyngeal space at the level of the base of the tongue.

The characteristic features above exist because the basicranium is the template that establishes the shape and perimeter of the facial growth field. The mandible attaches by its condyles onto ectocranial side of the middle cranial fossae, and the bicondylar dimensions thus determined by this part of the cranial floor. The nasomaxillary complex is suspended from endocranial fossae, and the width of the facial airway, the configuration of the palate and maxillary arch, and the placement of all these parts are thus established by it (36).

The facial and pharyngeal airway is a space determined by the multitude of seperate parts comprising its enclosing walls. The configuration and dimensions of the airway are thus a product of the composite growth and development of many hard and soft tissues along its pathway from nares to glottis.

Although determined by surrounding parts, those parts in turn are dependent upon the airway for maintenance of their own functional and anatomic positions. The airway functions as a keystone. A keystone is that part of an arch which stabilizes the position of the remaining parts of the arch.

The pharynx is a muscular tube that extends superoinferiorly from the base of the cranium to the level of the inferior surface of the body of the sixth cervical vertebra. The pharynx lies dorsal to the nasal cavity, oral cavity, and the larynx. The nasal part of the nasopharynx resembles the nasal cavity in possessing a highly vascular mucosa that is rich in lymphoid tissue. The mucosa of the nasal section of the nasopharynx is of the respiratory type, whereas the posterior part resembles the oropharynx in having a stratified squamous epithelium. The nasal portion of the nasopharynx has bony elements in its wall and is thus rigid, whereas the pharyngeal part is contractile as a result of the muscular nature of its wall. The nasopharynx begins superiorly at the attachment of the superior constrictor muscle to the pharyngeal tubercule on the basillar part of the occipital bone and ends at the level of the soft palate. This is the widest part of the pharynx and it communicates with the nasal cavity via choanae and with the middle ear cavities via the eustachian tubes (97).

The pharynx can be anatomically divided into two parts: an upper region (the nasopharynx) and a caudal area (the oropharynx). In dry skull material the bony nasopharynx is a conelike space that extends three dimensionally downward from the vomer's most dorsal contact point on the body of the sphenoid (hormion) to the level of the hard palate and the foramen magnum. During the growth process, this structure increases its volume by about 80%.

Transverse growth of the pharynx seems to level off at the end of the second year of life. Antero-posterior growth is small relative to the vertical component of growth and it is thought to stabilize during early infancy (122). The main component of growth of the pharynx is vertical, and it continues until adulthood (72).

Linder-Aronson and Leighton (70) characterized the growth of the posterior nasopharyngeal wall. They found that at age 5 the posterior wall of the pharynx displayed its greater thickness, and from age 5 to 10 underwent a decrease in thickness. Growth of the pharynx is influenced by the posterior cranial base growth, given that this bony structure represents its upper limit. The position and orientation of the maxilla and mandible are different in extreme vertical growth variations. In the long face pattern both the maxilla and the mandible are usually located in a more retrusive position. This has been interpreted as a mechanism to restore the pharyngeal space at the level of the tongue. An increase of space in both the oral cavity and pharynx occurs with growth. The hyoid bone descends providing more space for the tongue, the oral cavity increases its size.

For the pharynx, as for the face, different morphologic types and related growth behavior can be found. The posterior cranial base (the clivus) occupies a diagonal position in the cranium and makes up the posterior roof of the gablelike bony nasopharynx. As a consequence, its growth will influence the horizontal as well as the vertical pharyngeal dimension. Which component dominates depends entirely on its inclination. An obtuse Cranial base angle will open up the anteroposterior dimension of the pharynx, whereas an acute angle will contribute more to an increase in height (122).

4.2. Cranial Base Boundaries with Reference Points and Lines For Superimposition Purposes

The most common way of identifying the ACB is by the line sella-nasion (S-N). However, nasion is not technically part of the cranial base. This notation most likely came about due to the relative ease of localizing points N and S on a lateral cephalogram. Other external points such as glabella have also been chosen as the anterior limit of the ACB (51). Noteworthy is the fact that if glabella is chosen as the anterior limit in a growth study, then the influence of the frontal bone and sinus are excessive. On the basis of pure logic, choosing internal points to define ACB should yield more accuracy as the effects of facial structures will be eliminated. Unfortunately, the reality is that internal structures are often more difficult to locate on a radiograph.

Nasion is located on an anatomic edge and therefore easy to identify. Baumrind and Frantz (10) found that estimates of this point were quite good, but that the presence of outliers produced an unexpectedly large standard deviation. Because these outliers were so inaccurate, they were assumed to be the result of identifications of entirely different anatomic structures. Nasion stands as the most reliable and reproducible point to define ACB.

The posterior limit of the ACB is most commonly designated by sella, the midpoint of the pituitary fossa. However, Ford (40) preferred the pituitary point, which is the midline point on the anterior margin of the pituitary fossa. In other analyses, the posterior margin of the pituitary fossa is used. Baumrind and Frantz (10) found that midpoint sella was easily reproducible, and quite accurate, since it involves visual estimation of the center of a structure. This type of mental averaging system is known to yield low dispersion. In spite of some people's preference for the pituitary point, or marginal landmaks, sella has proven to be a popular and biologically valid reference point (51).

Most authors define the PCB as sella-basion (S-Ba). Generally sella is agreed on as the origin of PCB, but there is controversy over the terminus. In the early days of cephalometry, the large metallic ear rods used to orient the patient often obscured basion, so using this point was questionable. Bolton (Bo) point has also been considered, but is usually negated due to the difficulty in reproducing it on a radiograph. For these reasons, Bjork (13) induced articulare (Ar) as a fundamental reference point claming that it always shows up clearly. Interestingly, articulare is an artificially constructed point formed by the intersecting shadows of the occipital bone and the mandible. As film technique improved, the ability to locate basion also improved and its popularity soared (106).

The most common terminal points of ACB and PCB are N and Ba respectively. These points are logically used to arrive at the prevailing definition for total cranial base (TCB). Those authors that consider the terminal points of PCB to be Ar or Bo define TCB as N-Bo and N- Ar. Other authors consider TCB to be the sum of its collective parts: S-N + S-Ba (3, 15).

Reference lines are a means of comparing variations in shape on a uniform basis (15). The selection of a reference line is dependent on the purpose of the comparison. For example, if the various structures of the face and cranium are to be compared, the line can be more or less arbitrary, provided it can be readily defined and located. The ideal reference line is one that is stable in individuals over time. Any changes seen could then be recognized as movement of specific points relative to the stable references. The sella-nasion line, pioneered by Brodie (16), is used frequently as a reference for superimposition. Both sella and nasion are easily identified points and the superimpositions produce consistent and reliable patterns.

Coben (23) described basion-articulare (Ba-Ar), for the posterior cranial base reference points, as his ideal reference line to evaluate growth, and found it to be essentially stable post-natally over time.

4.3. The Interaction Between The Craniofacial Anomalies and Craniofacial Morphology

Children with craniofacial anomalies often have a complex array of problems. Furthermore, their growth and development may be affected in a predictable fashion based on their syndromic diagnosis.

Craniosynostoses are disorders characterized by premature fusion of one or more cranial sutures before brain growth is complete. Fusion of a single suture is most common, and, most often, the fusion is present at birth. Premature fusion of one or more sutures results in an abnormally shaped head because the brain, despite the restriction in growth caused by the closed suture/sutures, compensates by growth in regions where the cranial sutures have not yet closed. The etiology of craniosynostosis might in some cases be inherited and caused by specific genes or metabolic diseases, whereas the etiology in other cases remains unknown (25). The incidence of craniosynostosis is relatively rare, with an incidence of approximately 0.4%.

A diagnosis of craniofacial dysostosis encompasses many syndromes of which the most common are Apert, Crouzon and Pfeiffer's syndromes. All have craniosynostosis with some degree of midface hypoplasia and other abnormalities, including hypertelorism and proptosis. The mandible is of normal size and, but appears to be relatively prognathic secondary to the midface hypoplasia. The palate is high and arched, while the nasal passages are small with some degree of choanal stenosis (19). As a result, these patients are primarily mouth breathers. The characteristic pharyngeal attenuation in these patients appears to be partly the result of early synostosis of the spheno-occipital synchondrosis. This precipitates an especially short posterior cranial base with a resultant reduction of pharyngeal height. The nasal height and depth are also decreased (101).

4.4. The Association Between Cranial Base Angle with Dental and Skeletal Variables

The two limbs of the cranial base form a flexion at sella. The maxilla appears attached to the anterior segment and the mandible to the posterior segment. It would be reasonable to assume, just from this geometric relationship, that any change in flexion would alter maxillary and mandibular positions relative to the cranial base as well as to each other. This in turn may influence the skeletal pattern and type of malocclusion.

There is an abundance of contradictory literature relating the cranial base flexure to the classification of malocclusion and the degree of mandibular prognathism. One group contends that the cranial base flexure has effect on the class of malocclusion or mandibular prognathism (14, 15), whereas others contend that the cranial base flexure is not a factor (68, 136).

Anderson and Popovich (3) studied subjects with small and large cranial base flexure at the age of 6 years. During the longitudinal follow-up they found that the group with the flatter cranial base flexure had Angle Class II occlusion 45% more frequently. In the group with the closed cranial base angle, the condyles were more forward and downward, but no Class III occlusions were found. The same year they studied the horizontal positioning of the maxilla and mandible relative to the cranium in children with Angle Class I and II malocclusions, comparing Cranial base angle, upper and lower cranial height and correlations between those variables (4). They found that the Cranial base angle was larger in children of the Angle Class II group than in Class I. The correlation of the Cranial base angle with lower cranial height (the distance between Bolton and Sella) was strongly negative in both groups.

The previous study was continued as the comparison of correlations in these same Class I and Class II groups by contrasting the correlations among Cranial base angles, cranial base dimensions, mandibular angles, and dimensions (5). The interrelations of Cranial base angles and mandibular angles were stronger in the Class II group, whereas, the correlation of these angles with cranial base dimensions was stronger in the Class I group. Correlations of mandibular dimensions with mandibular angles, and with Cranial base angles and dimensions, were similar in Class I and II groups. Thus when cranial base and mandibular angles corrolate with posterior cranial base length, the occlusion tends to be normal or Class I, but when the angles corrolate more with each other, the occlusion tends toward Class II. It is more important shape relate to size than to shape (5).

Wilhelm et al (136) compared the cephalometric measurements of the cranial base in subjects with Class I and Class II skeletal patterns at ages 1 month, 2 years, and 14 years. They evaluated no significant differences between the skeletal classes at any of the 3 ages. Their study indicates that cranial base growth patterns are similar for Class I and Class II subjects and that the premise of a more obtuse Saddle angle or Cranial base angle in Class II skeletal patterns was not supported.

On the other hand Dhopatkar et al (28) evaluated the relationship between the degree of Cranial base angle and type of malocclusion, a retrospective study was carried out to examine the contribution of Cranial base angle in the four groups of malocclusion, their results showed that the Cranial base angle was found to be significantly larger in Class II division I subjects than in the Class I groups, and this difference was not seen between Class I subjects and the other two malocclusion groups.

Andria et al (6) also studied the correlation of cranial base flexure and the degree of mandibular prognathism and classification of malocclusion. Their study evaluated the correlation of the pretreatment Cranial base angle and its component parts to other dental and skeletal cephalometric variables, and found that the cranial base or Saddle angle by itself does not appear to have any statistical significance to the position of the chin in the profile, the incisor relationships, the alveolar points A and B, or the length of treatment time. In contrast, the posterior Cranial base angle had a statistically significant negative correlation to both the skeletal facial angle and the alveolar point reflecting a more posterior skeletal and alveolar position of the mandible which indicates that the posterior cranial base leg is the controlling factor in relating the cranial base to mandibular prognathism.

The significance of cranial base flexure as an early factor in the etiology of malocclusion remains controversial. Kerr and Hirst (61) investigated longitudinal growth changes and concluded that the Cranial base angle at 5 years of age is an accurate predictor of the occlusal type at 15 years of age in 73% of the subjects. On the other hand Varrela (130) investigated characteristics of a sample of Class II patients between 3 and 7 years of age and did not find the cranial base to be different in these patients compared with a Class I control group. The author concluded that the cranial base is not an early etiologic factor in Class II skeletal relationships. Klocke (65) also investigated skeletal features in patients with small and large Cranial base angles. Subjects with a large Cranial base angle in the primary dentition demonstrated a skeletal Class II tendency both at the initial observation and at the longitudinal follow-up. He concluded that the relationship between cranial base flexure and skeletal pattern of the jaws seems to be established before the age of 5 years.

Little emphasis has been placed on the morphological characteristics of the cranial base in Class III malocclusion. Craniofacial features reported to be associated with this anomaly include an acute Cranial base angle and a shortened cranial base length as compared with Class I subjects (56, 58). However, the role of the cranial base is discussed controversially and some authors even contend that Class III cranial base morphology does not differ from that associated with a normal Class I profile (4, 8). In conjunction with these, Proff et al (98) investigated the cranial base configuration in skeletal Class III patients to clarify the conflicting findings from literature. They showed that in contrast to overall cranial base length, the anterior (N-S) and posterior (S-Ba, S-Ar) sections failed to show a significant reduction in Class III patients. The significantly more acute angles (Ca-S Ba and Se-S-Ba) reflected increased cranial base flexure.

4.5. The Association Between Cranial Base Angle and Upper Airway

Physiologic factors have received particular attention with regard to their possible relation to craniofacial development, namely, the adequacy of the nasopharyngeal airway and the postural relations of the head and the cervical column. Studies of different samples have demonstrated associations between craniocervical angulation and craniofacial morphology, between airway obstruction and craniofacial morphology, and between airway obstruction and craniocervical angulation.

Trenouth (123) evaluated the association between the functional oropharyngeal airway and craniofacial morphology. Their sample consisted of 70 subjects (31 males and 39 females), 10 to 13 years of age, and 16 craniofacial variables were measured on lateral cephalometric radiographs. Cases with Frankfort Horizontal more than 10° above true horizontal were rejected. Oropharyngeal airway was positively correlated with the length of mandible, with the distance between the third cervical vertebra and the hyoid bone, and with the Cranial base angle.

Associations of Class II malocclusions and vertical growth pattern with obstruction of the upper and lower pharyngeal airways have been suggested. This implies that this malocclusion characteristics have a predisposing anatomical factor for this problem. In relation to this, Freitas et al (41) compared upper and lower pharyngeal widths in patients with untreated Class I and Class II malocclusions and normal and vertical growth patterns. Their sample comprised 80 untreated subjects, mean age of 11.64 years, divided into 2 groups: 40 Class I and 40 Class II, subdivided according to growth pattern into normal and vertical growers. They showed that the upper pharyngeal width in the subjects with Class I and Class II malocclusions and vertical growth patterns was statistically significantly narrower than in the normal growth pattern groups. However, they concluded that the malocclusion type does not influence upper pharyngeal airway width, and malocclusion type and growth pattern do not influence lower pharyngeal airway width.

Generally, pharyngeal airway space is measured on lateral skull radiographs. When measuring the pharyngeal airway space it is important to consider how the changes in head posture affect the size of the pharyngeal airway (50). Many studies have reported that the natural head position (mirror position) when taking radiographs varied among individuals, and it is found clinically that the natural head posture of individuals varies at different points in time (77, 90, 92, 111). When determining the difference between the pre- and post-operative pharyngeal airway space of patients with dentofacial deformity or when studying the relationship between pharyngeal airway space and craniofacial morphology, one should always be aware of how head posture affects the results. Hellsing (50) reported that the change in lordosis produced by changing the natural head posture to 20° extension had a significant correlation with the change in the craniocervical inclination and pharyngeal airway space. Muto et al (84) investigated the relationship between craniocervical inclination and pharyngeal airway space by measuring the parameters at different head postures in the same subject to obtain a regression equation to correct the values measured. Fifty lateral cephalometric radiographs taken at five different head postures per individual were obtained from ten adults (seven males and three females) aged from 25 to 30 years with nose breathers and Class I occlusion. The OPT/NSL (cranio-cervical inclination in the second vertebrae) and C3-Me (distance between the third vertebrae and the Menton) correlated strongly with PAS-TP (the most proximal distance measured between the posterior pharyngeal wall and the tongue base). The regression equations were obtained and from these equations they concluded that an increase of 10° in OPT/NSL or 10 mm in C3-Me distance increased the pharyngeal airway space (PAS-TP) by about 4 mm.

There have been many studies on the relative positional relationship between the hyoid bone and airway (30, 31). The hyoid bone is connected to the pharynx, mandible, and cranium through muscles and ligaments (12). It is the only bone of the body that has no bony articulations. The hyoid bone and its connecting muscles are also part of the oropharyngeal complex. Without the hyoid bone, our facility for maintaining an airway, swallowing, preventing regurgitation, and maintaining the upright postural position of the head could not be controlled as carefully (124).

Tallgren and Solow (117) examined hyoid position, facial morphology and craniocervical posture in adult subjects with a complete or nearly complete dentition. The material consisted of lateral head films divided into three groups, aged 20-29, 30-49 and 50-81 years. Their results showed that the mean vertical distances from the hyoid to the upper face, the mandible and the cervical column were significantly greater in the older age groups, correlation analysis further indicated that a large hyo-mandibular distance (Hy to ML) is associated with a large mandibular inclination (NSL/ML). The position of hyoid in relation to the cervical column showed less variability than the hyoid relationship to the maxilla and the mandible.

Enlarged tonsils, adenoids, and chronic respiratory problems have been associated with the compensatory adaptations of natural head posture in children. Obstructive Sleep Apnoea (OSA) results from the repeated obstruction of the upper airway during sleep. Recently it has been shown that adult patients with OSA also tend to exhibit a craniocervical extension with a forward head posture (112, 118). This may be attributed to the compromised morphology, and/or physiology of the upper airway and related structures observed in OSA patients which persist to some extent even when they are awake (75, 118, 119, 126). Experimental studies demonstrated an immediate head extension and changes in postural EMG activity in the craniofacial muscles following the obstruction of the nasal airways (49, 131). The purpose of the study of Özbek (92) was to determine if the severity of OSA disease, obesity, and/or the cephalometric measurements of the upper airway, tongue, soft palate, and hyoid bone position are related to the individual differences in natural head posture of OSA patients. He found that the craniocervical extension and forward head posture in OSA patients were associated with a higher disease severity, a longer and larger tongue, a lower hyoid bone position in relation to the mandibular plane, a smaller nasopharyngeal and a larger hypopharyngeal cross-sectional area, and a higher body mass index.

Many cephalometric studies have shown craniofacial abnormalities in OSA patients. Despite that observed alterations in craniofacial morphology are not uniform, a steeper mandibular plane angle, a shorter mandibular body length, and a low hyoid bone position were consistently reported by most investigations (81). Tangugsorn (118) analyzed the cervico-craniofacial skeletal morphology in 100 male patients with OSA, and reported that dimension of cranial base was shorter with slight counter-clockwise rotation and depression of clivus, maxilla and mandible were retrognathic related to nasion perpendicular plane (N⊥FH) despite normal angles of prognathism, 47% of the OSA group had mandibular retrognathia, the size of bony pharynx was reduced, hyoid bone was inferiorly positioned and head posture was deviated with larger craniocervical angle.

Özdemir et al (93) evaluated comprehensively the cephalometric features of children with suspected OSA, and elucidated the relationship between cephalometric variables and apnea/hypopnoea index (AHI) severity. Cranial base angles were found to correlate with increasing levels of AHI scores, protrusion of the maxilla (SNA) and mandible (SNB) did not correlate with AHI scores, The length of the mandibular plane (GnGo) and the minimal posterior airway space (MPAS) were inversely correlated with AHI scores, there was positive correlation between MPAS and GoGn and negative correlation between MPAS and gonial angle.

Nelson et al (87) examined the differences in craniofacial factors between snorers and nonsnorers from childhood to adulthood. They reported that posterior airway space was significantly smaller for snorers at adulthood and concluded that snorers exhibit a lowered hyoid position from childhood.

Activators are considered to enhance skeletal growth of the mandible. In relation to this pharyngeal airway dimension changes by these devices, Özbek (91) examined the use of functional orthopedic devices in increasing oropharyngeal airway dimensions in children with Class II skeletal patterns and clinically deficient mandibles. His results clearly suggested the existence of a relationship between functional orthopedic treatment and increases in oropharyngeal airway dimensions in certain skeletal Class II growing subjects, but he also concluded that it would be premature to arrive at general clinical conclusions like if increasing oropharyngeal airway dimensions by means of functional orthopedic treatment in cases with mandibular deficiency will prove to have favorable outcomes, such as modification of growth pattern of the craniofacial structures and/or a reduced chance of having impaired respiratory function in short and long term.

Hänggi et al (47) also evaluated the physiological changes in the pharyngeal airway size in healthy children and compared them with a group of children who received activator-headgear treatment to determine possible treatment effects. Their findings indicated that activator-headgear therapy (followed by fixed appliance treatment) has the potential to increase pharyngeal airway dimensions, such as the smallest distance between the tongue base and the posterior pharyngeal wall or the pharyngeal area. Importantly, this achieved increase seems to be maintained in the long term, up to 22 years on average according to the findings of their research.

In 2008, Muto (86) et al examined the relationship between craniofacial morphology and the posterior airway space in patients with mandibular deformities (mandibular retrognathism and mandibular prognathism), as compared to normal subjects. The pharyngeal airway diameter was the largest in the group with mandibular prognathism, followed by the normal mandible and mandibular retrognathism groups, respectively. Their results indicated that the antero-posterior dimension of the posterior airway space is affected by different skeletal patterns of the mandible.

Hiyama (53) examined the changes in mandibular position and oropharyngeal structures that were induced by wearing of cervical headgear during sleep only. His samples were in supine position. They found no significant anteroposterior mandibular displacement. The sagittal dimension of the upper airway was significantly reduced, however, no significant changes were observed in the vertical length of the upper airway.

The studies have documented that the mandibular growth induced by a functional appliance for growing patients with Class II malocclusions had a beneficial effect on the constricted upper airway. Considering that mandibular growth has a definite influence on the upper-airway dimension, it can be speculated that maxillary growth could also have beneficial effects on the upper airway. It was recently reported that rapid maxillary expansion could induce a change in the respiratory function and it could be a useful treatment modality for patients with obstructive sleep apnea (22). Hiyama (54) examined the effect of changes in craniofacial structures on the upper-airway dimension. As an aid in modifying maxillary growth, a maxillary protraction appliance in combination with a chin cap was used in their study. Their results showed that a significant increase in maxillary forward growth, inhibition of mandibular forward growth, and clockwise rotation of the mandible were observed. Maxillary growth had a significant positive effect on the superior upper-airway dimension. These findings indicate that the superior upper-airway dimension càn be altered during maxillary protraction.

Maxillary displacement can be easily achieved using rapid palatal expansion. Using both appliances (RPE + protraction headgear) combined can weaken the sutural junctions of the maxilla with the other nine bones of the craniofacial structure and allows the protraction force to work effectively (11, 43). Palatal expansion with protraction headgear is an accepted and routine part of the treatment of Class III malocclusions (127). Sayınsu et al (105) evaluated the effects of rapid palatal expansion (RPE) used in conjunction with maxillary protraction headgear on the sagittal dimension of the airway. The result of their study showed that point A moved anteriorly, the palatal plane showed a counter-clockwise rotation matching the clockwise rotation of the mandible as revealed by the decrease in SNB angle, and the vertical parameters showed a statistically significant increase, the head was in a more extended position in relation to the cervical vertebrae, nasopharyngeal airway measurements showed a mean increase. Maxillary disarticulation and protraction improved naso- but not oropharyngeal airways. The results of this study should be interpreted with caution because of lack of control group. However Kılınç (62) examined the effects of rapid palatal expansion and maxillary protraction headgear therapy in 18 patients with a skeletal Class III malocclusion on upper airway dimensions compared with an untreated control group. When he compared the treatment and control groups, the upper airway linear measurements and the nasopharyngeal area had increased in the treatment group.

Both mandibular setback surgery and bimaxillary surgery can improve occlusion, masticatory function, and esthetics by markedly changing the position of the mandible (102). Several studies attempted to investigate the effect of orthognathic surgery on the pharyngeal airway space in patients with Class III skeletal deformities. Chen et al (20) compared the short-term and long-term effects of bimaxillary surgery with those of mandibular setback surgery concerning pharyngeal airway measurements at 3 levels: nasopharynx, oropharynx, and hypopharynx. He found that cephalometric evaluation of patients undergoing mandibular setback surgery showed a significant reduction at the oropharyngeal and hypopharyngeal levels over the short and long terms, in contrast, bimaxillary surgery caused an increase at the nasopharyngeal level and decreases at the oropharyngeal and hypopharyngeal levels only in the short term, whereas no significant change was seen in the long term, and he concluded that bimaxillary surgery therefore might have less effect on reduction of the pharyngeal airway than mandibular setback surgery only. The surgeon should consider bimaxillary surgery rather than mandibular setback surgery to correct a Class III deformity to prevent the development of obstructive sleep apnea.

Değerliyurt (27) also evaluated the morphologic changes of the upper airway space in Class III patients who underwent mandibular setback or bimaxillary surgery (maxillary advancement and mandibular setback) by means of computed tomography at 2 levels: soft palate and base of tongue. Anteroposterior, lateral, and cross-sectional area dimensions of the airway at the level of soft palate and base of tongue were measured pre- and postoperatively on computed tomography images. According to his results anteroposterior dimensions of the airway decreased in both groups; however, the reduction was significantly less in cases treated with bimaxillary surgery. In the mandibular setback surgery group, the cross-sectional area of the airway decreased significantly. Although the cross-sectional area of the airway decreased in the bimaxillary surgery group, the reduction was not statistically significant. He, as Chen (20) did, suggested that bimaxillary surgery can prevent narrowing of the upper airway in the correction of Class III deformities in comparison with mandibular setback surgery used as the sole treatment.

The effect of mandibular advancement and setback surgery on the pharyngeal airway space has been reported by different investigators but Mehra et al (79) looked specifically at the effects of counterclockwise rotation of the maxillomandibular complex (decrease of the occlusal plane angle) on the pharyngeal airway space. When counterclockwise rotation of the maxillomandibular complex is performed, the genial tubercles move forward a greater amount than the teeth, thereby maximizing the forward movement of the hyoid bone, the base of the tongue, and other associated soft tissues. He evaluated the effects of double-jaw surgery with counterclockwise rotation of the maxillomandibular complex on the pharyngeal airway space and velopharyngeal anatomy in patients with high occlusal plane facial morphology and found that there was an increase in pharyngeal airway space at the soft palate and at the base of the tongue relative to the amount of mandibular advancement in the patient group who underwent maxillary and mandibular advancement, and a decrease in pharyngeal airway space at the soft palate and at the base of the tongue relative to the amount of mandibular setback in the patient group underwent maxillary advancement and mandibular setback.

Battagel et al (9) examined the alterations in airway and hyoid position in response to mandibular advancement in subjects with mild and moderate OSA. They found that mandibular advancement is associated with a proportionate increase in oropharyngeal dimensions whereas the amount and direction of response of the hyoid to mandibular protrusion has a wide variation.

Mandibular advancement with bilateral sagittal split osteotomy is a well established and versatile procedure used to treat mandibular retrognathism. It is known that the oropharyngeal complex is also affected by the surgery. The oropharyngeal complex consists of the hyoid bone, with its connecting muscles, and the pharyngeal airway. Previous studies have shown that there are changes in the position of the hyoid bone and in pharyngeal size in connection with mandibular advancement. After the surgery, anterior displacement of the hyoid bone has been noted (67, 124). The purpose of Eggensperger's study (30) was to determine long-term changes in hyoid bone position and pharyngeal airway size after mandibular advancement. The final position of the hyoid bone was more posterior than it had been preoperatively. The upper and middle pharyngeal airways were narrower than their preoperative values. She concluded that mandibular changes influence hyoid bone position during the entire postoperative period, whereas stretching of suprahyoidal musculature seems to contribute to skeletal relapse and also mandibular advancement surgery alone possibly does not achieve a stable increase of pharyngeal airway size over a long-term period of 12 years. The same year she evaluated (31) the long-term changes in hyoid bone position and pharyngeal airway size after mandibular setback osteotomies. Following the initial decrease after surgery, the size of the lower pharyngeal airway remained almost unchanged. The upper and middle pharyngeal airway sizes continued to decrease over the postoperative period of 12 years. The hyoid bone moved posteriorly and inferiorly related to the setback surgery. At long-term follow-up, the hyoid bone adapted horizontally to a position about 1.6mm more posterior than its preoperative location (31).

5. MATERIALS and METHOD:

5.1. Case Selection Criteria

This study is based on the initial cephalometric radiographs of patients who were treated at the Marmara University Faculty of Dentistry Department of Orthodontics. Among 2000 lateral cephalometric radiographs screened, 250 lateral cephalometric radiographs (150 female, 100 male) were selected according to the following criteria;

- All subjects were Caucasian whose ages were between 16-19 years (The mean age was 17.20±1.00.)
- Patients had no cleft lip and/or palate and craniofacial syndromes, had no previous orthodontic treatment and adenoidectomy operation
- Lateral cephalometric head films were of excellent quality with good resolution of reference points

5.2. Machines Used in Cephalometrics

The cephalometric radiographs were taken by two different cephalometric machines at Marmara University Faculty of Dentistry Oral Diagnosis and Radiology Department. One of the machines was J.Morita MFG Veraviewapocs (Kyoto, Japan, 2004). The radiographic enlargement was indicated by a millimeter scale incorporated in the machine, which was 1:1,05. The enlargement value was taken into consideration while linear cephalometric measurements were done. The distance between the x-ray source and subjects' ortho-axial plane was 180 cm. The second machine was Siemens Orthopos C/CD 3200 (Germany). The radiographic enlargement ratio was 1:1. The distance between x-ray source and subjects' ortho-axial plane was 200 cm. All radiographs were taken when subjects were on upright position.

5.3. Cephalometric Measurements

Certain conventional anatomic points were marked (Figure 1). These were joined (Figure 2) to give 9 angular (Figure 3) and 7 linear variables (Figure 4), and also the cross-sectional area of pharyngeal airway space (Figure 5) was evaluated.

Anatomic points (Figure 1);

1- S : Midpoint of fossa hypophysealis
2- N : Anterior point at frontonasal suture
3- A : Deepest anterior point in concavity of anterior maxilla
4- B : Deepest anterior point in concavity of anterior mandible
5- Me : Most inferior point of bony chin
6- Go : A mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible
7- ANS : Most anterior point of anterior nasal spine
8- PNS : Most posterior point of hard palate
9- Ar : A mid-plane point at the intersection of posterior ramus with inferior cranial base
10- Ba : Most inferior point on anterior foramen magnum
11- Hy : Most anterosuperior point of hyoid
12- C3i : Most anteroinferior point on the body of the third cervical vertebra
13- Cv2ig : The most superoposterior extremity of the odontoid process of the second cervical vertebra
14- Cv2ip : The most inferoposterior point on the body of the second cervical vertebra

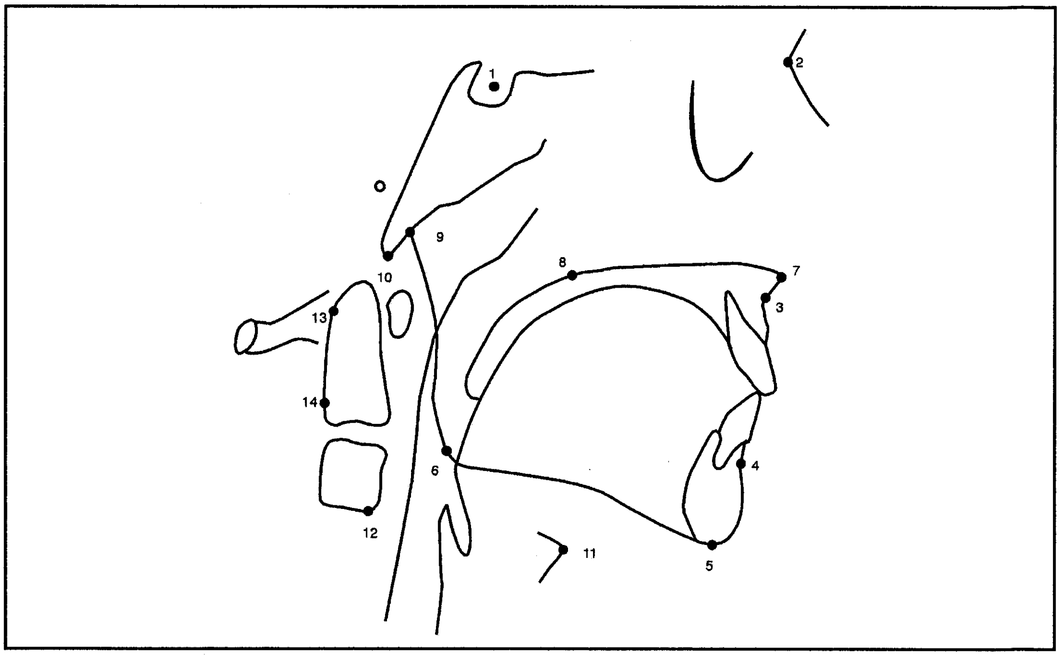

Figure 1. Landmarks used in lateral cephalometric analysis

Based on the anatomical points mentioned above, the following planes are traced (Figure 2);

15- NSL : Line through N and S
16- ML : Mandibular line through Me and Go
17- PRL : Posterior ramus line through Ar and Go
18- MaxL : Line through ANS and PNS
19- OPT : Line through Cv2ig and Cv2ip
20- NA : Line through N and A point
21- NB : Line through N and B point

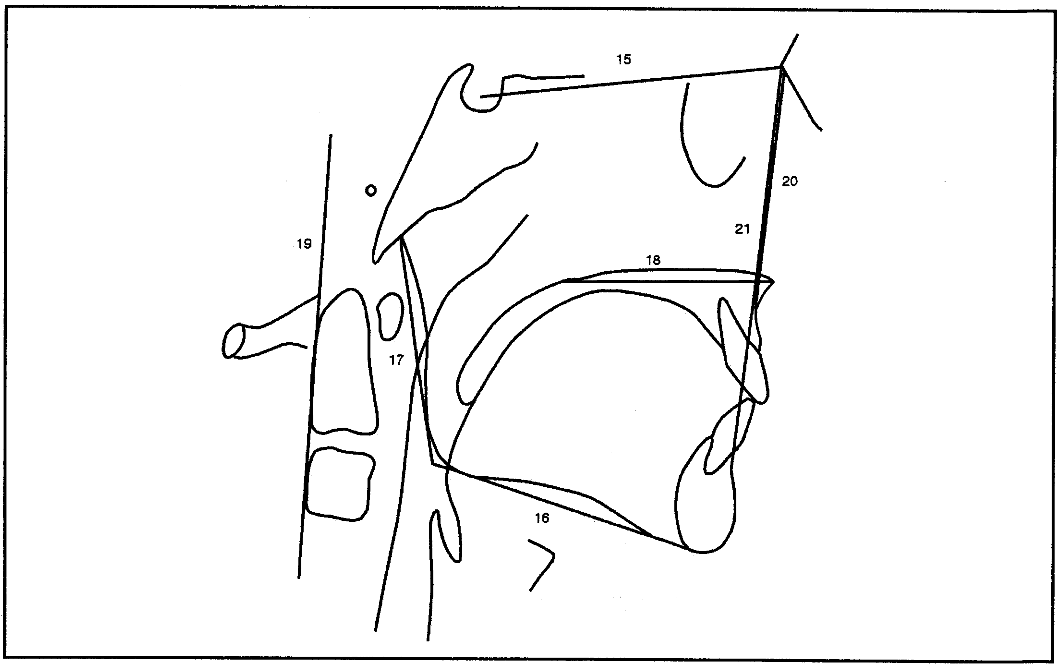

Figure 2. Planes used in lateral cephalometric analysis

Following angles were constructed (Figure 3);

22- Saddle angle (Cranial base angle), (Nasion-Sella-Articulare)
23- Sella Nasion (SN) – Maxillar Plane (ANS-PNS) angle
24- OPT - NSL angle (Craniocervical inclination in the second vertebrae with sella nasion line)
25- Sella – Nasion - A point (SNA angle)
26- Sella – Nasion - B point (SNB angle)
27- A point – Nasion - B point (ANB angle)
28- Sella Nasion - Mandibular plane (SN-GoMe angle)
29- Frankfort horizontal plane (FH) - Mandibular plane (MP) (FMA angle)
30- Gonial angle (between mandibular and posterior ramus planes)

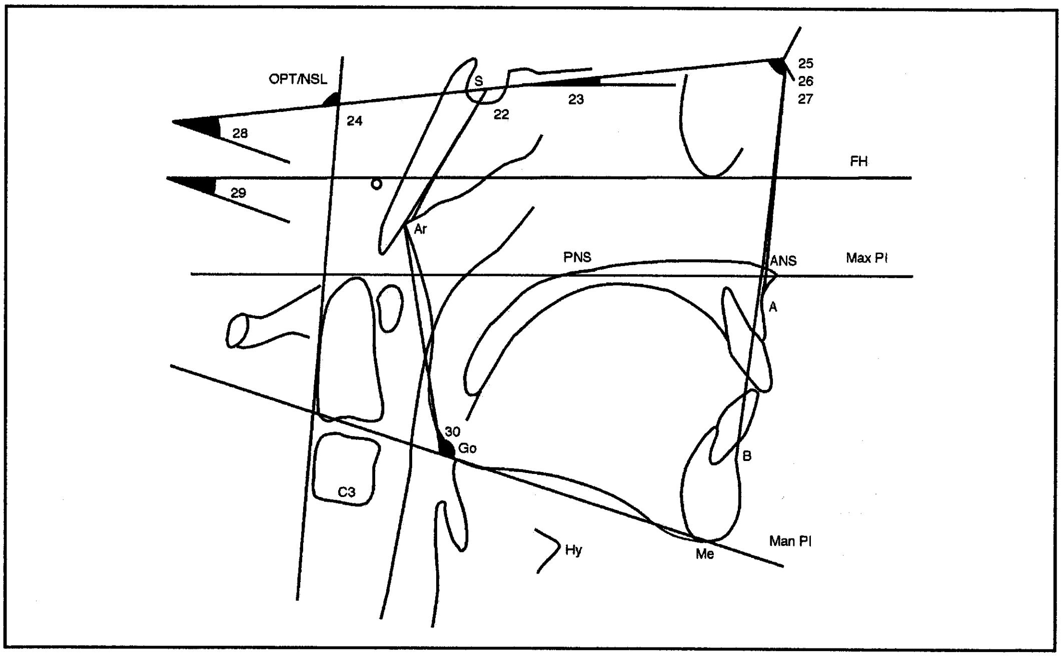

Figure 3. Angular measurements used in lateral cephalometric analysis

Linear and area measurements used in the study are (Figure 4);

31- Nasion – Sella (SN) distance (mm)

32- Go – Me distance (mm)

33- Hy - C3i distance (anterosuperior corner of hyoid and anteroinferior corner of 3rd vertebrae) (mm)

34- Mandibular Plane (MP) - Hy (anterosuperior corner)(perpendicular distance from Hy to Mandibular plane) (mm)

35- ad1 (the distance between the point on the posterior pharyngeal wall where a line perpendicular to sella (S) – Ba plane passing through PNS intersects the posterior pharyngeal wall and PNS) (mm)

36- PAS-UP (minimal pharyngeal airway space between the uvula and the posterior pharyngeal wall, parallel to FH plane) (mm)

37- PAS-TP (Minimal pharyngeal airway space between the back of the tongue and the posterior pharyngeal wall, parallel to FH plane) (mm)

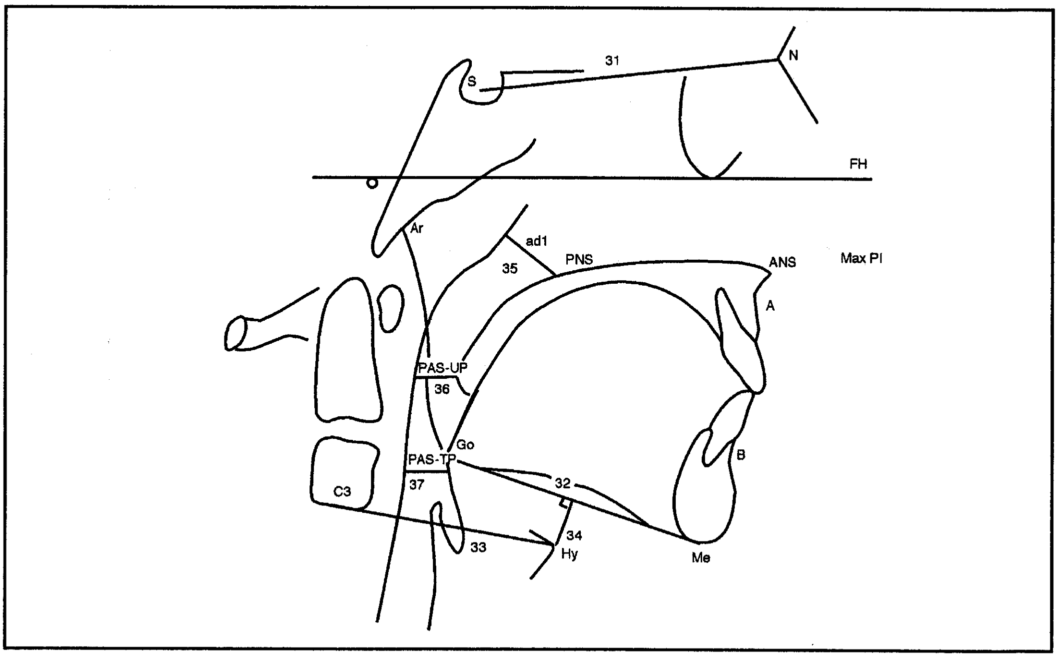

Figure 4. Linear measurements used in lateral cephalometric analysis

The cross-sectional area of pharyngeal airway space (Figure 5) was evaluated;

38- The cross-sectional area of oropharynx (The area between the ANS-PNS line, posterior pharyngeal wall, uvula and a parallel line to ANS-PNS which passes through epiglottis) (mm^2)

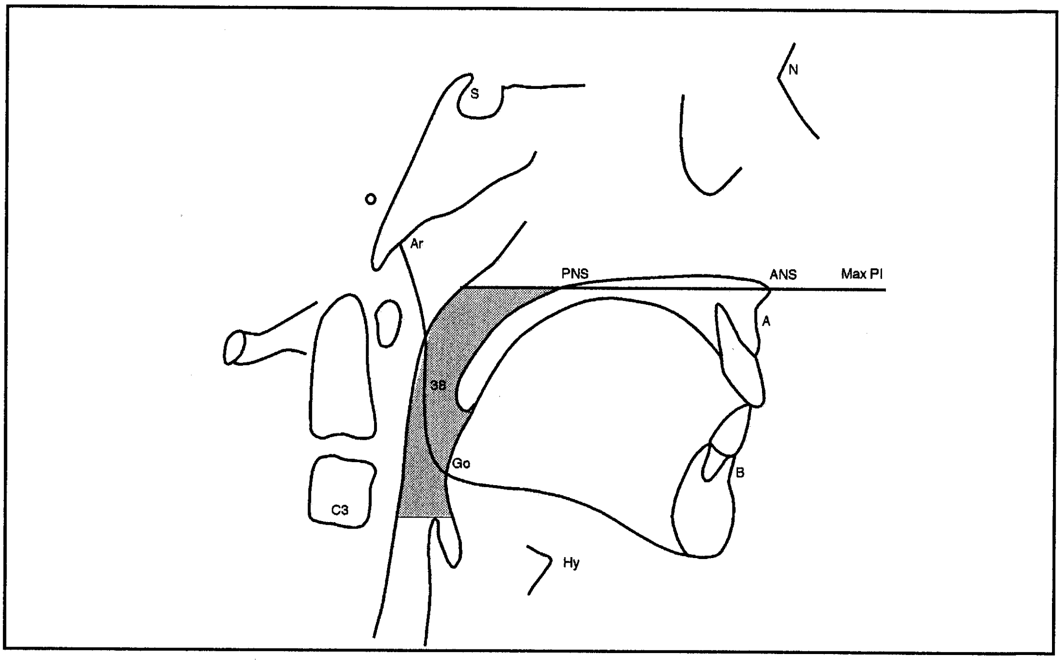

Figure 5. The pharyngeal airway measurement on lateral cephalometric analysis

The cephalometric radiographs were traced and the reference points (50, 109) were marked on the films for each subject simultaneously by the same researcher (IS) to be able to obtain maximum agreement when marking. Permenant pen on acetate paper over an illuminated opal light box was used.

Anatomic landmarks and reference planes were traced manually, using conventional methods. Later, the tracings on the acetate paper were transfered to computer by using an hp psc 1100/1200 scanner. AutoCAD R 17.2 software (AutoDesk Co, 2009, USA) was used to measure the oropharyngeal area, and other distances digitally (Figure 6).

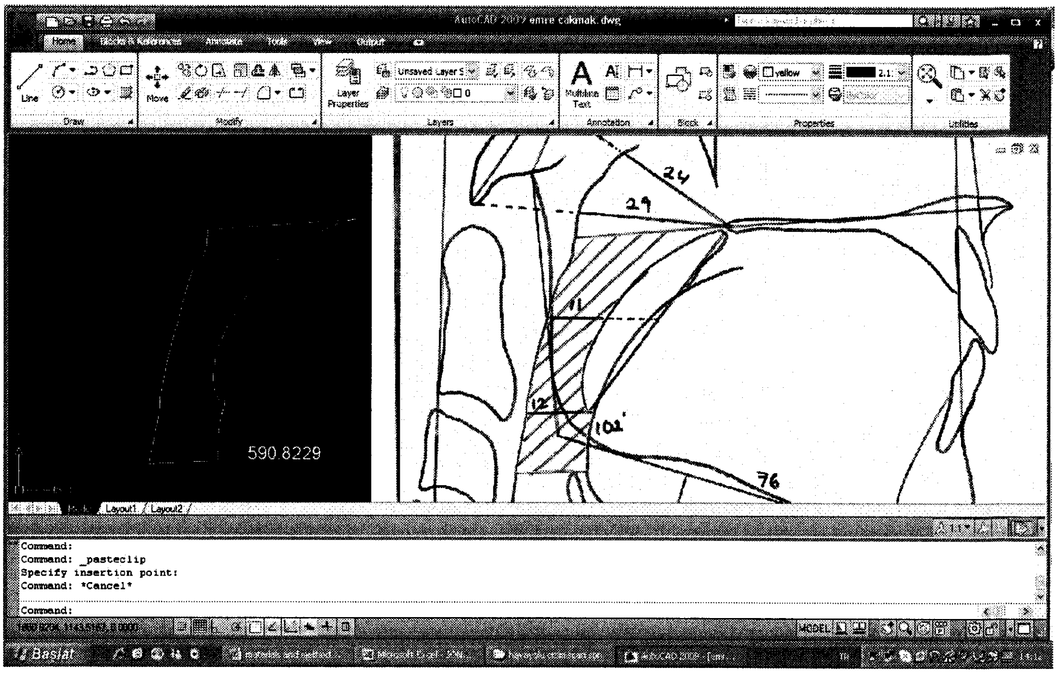

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Figure 6. Measuring the area of the oropharyngeal airway on the AutoCad software

While evaluating the pharyngeal airway space it is important to consider how the changes in head posture affect the size of the pharyngeal airway (48, 50). Many studies have reported that the natural head position (mirror position) when taking radiographs varied among individuals (77, 90, 92, 109, 111) and clinically it has been shown that the natural head posture of individuals varies at different points in time. When studying the relationship between pharyngeal airway space and craniofacial morphology, one should always be aware of how head posture affects the results. Hellsing (50) reported that the change in lordosis produced by changing the natural head posture to 20° extension had a significant correlation with the change in the craniocervical inclination and pharyngeal airway space.

The study of Muto et al (84) also demonstrated a significant relation between head posture and pharyngeal airway space: a change in craniocervical inclination of 10° altered the pharyngeal airway space by about 4 mm. Based on these findings, in the present study the study group was evaluated by two different ways. In the first evaluation, in order to eliminate the effect of head posture on the pharyngeal airway space, the pharyngeal airway space measurements were corrected according to Muto et al's findings (84, 85). The regression equations were;

$y = -14.063 + 0.258x$, for PAS-UP, (y = Corrected PAS-UP and x = OPT/NSL),
$y = -27.177 + 0.39x$, for PAS-TP, (y = Corrected PAS-TP and x = OPT/NSL).

In the second evaluation, the samples showing Frankfort horizontal plane-true horizontal angle more than 10° were eliminated like Trenouth et al have suggested (123). The oropharyngeal area, bordered by ANS-PNS line above, and a paralel line on the level of epiglottis below, and ad1 (nasopharyngeal area) were correlated with the cephalometric variables, PAS-UP and PAS-TP of the samples were not corrected in this evaluation.

5.4. Statistical Method

Statistical Analysis of the study's data was performed by using NCSS 2007 & PASS 2008 Statistical Software (Utah, USA) programme.

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 genders. During the evaluation of study data, besides the descriptive statistics including Mean, Standard Deviation, Oneway ANOVA test was utilized to determine whether significant differences existed between groups. Tukey`s HSD (honestly significant difference) test was performed for a multiple comparison procedure among all possible pairs. Student t test was used for the comparison of parameters with normal distribution between two groups.

Pearson's correlation coefficient test was used to detect any relationship between airway measurements, Saddle angle and other variables.

5.4.1. Error of the method

Twenty lateral cephalograms obtained from randomly selected subjects were retraced and reanalyzed two weeks later by the same investigator, and the method error for each variable was calculated to determine measurement reproducibility. Intraclass correlation coefficent (ICC) was calculated for the analysis of method error of the parameter measurements. The results were in 95% confidence interval. Statistical significance level was indicated by $p<0.05$.

6. RESULTS

6.1. Measurement Error (Table 1)

Twenty lateral cephalograms obtained from randomly selected subjects were retraced and reanalyzed two weeks later by the same investigator, and the method error for each variable was calculated to determine measurement reproducibility. For the cephalometric mesurements intraclass correlation coefficients within the patients, 95% confidence intervals and intraobserver reliability were calculated (Table 1).

Table 1. Reliability of cephalometric measurement

	Intraclass correlation coefficient	**95% Confidence Interval**	
SNA	0,999	0,998	1,000
SNB	0,998	0,996	0,999
ANB	0,991	0,977	0,996
Saddle angle	0,998	0,995	0,999
SN-GoMe	0,998	0,996	0,999
FMA	0,998	0,995	0,999
SN-PP	0,995	0,987	0,998
Gonial	0,999	0,997	1,000
OPT-NSL	0,999	0,998	1,000
S-N (mm)	0,999	0,998	1,000
Go-Me (mm)	0,996	0,990	0,998
Hy-C3i (mm)	0,997	0,993	0,999
Hy-Mn Pl (mm)	0,999	0,997	1,000
ad1 (mm)	0,998	0,996	0,999
PAS-UP (mm)	1,000	1,000	1,000
PAS-TP (mm)	0,990	0,975	0,996
Oropharyngeal Area (mm^2)	1,000	1,000	1,000

The intraclass correlation coefficient was found to be close to the value of 1.00. The lowest correlation coefficient was noticed in the measurement of PAS-TP (0.990). Findings in relation to method error suggest that cephalometric tracings and measurements of distances, angles and airway area are reliable and within acceptable limits (Table 1).

6.2. Lateral Cephalometric Evaluation

6.2.1. Evaluation of angles for both sexes (Table 2)

When the cases (n=250) were divided into males (n=100) and females (n=150), and their craniofacial measurements were compared, SN-GoMe (p<0.05), SN-PP (p<0.01) and OPT-NSL (p<0.01) were found to be significantly higher for females than males (Table 2).

Table 2. Evaluation of angles for both sexes

	Female (n=150)	**Male (n=100)**	*p*
	Mean±SD	**Mean±SD**	
SNA	79,23±3,68	79,71±4,01	***0,329***
SNB	76,15±4,45	77,28±4,84	***0,060***
ANB	3,08±0,28	2,43±0,35	***0,151***
Saddle angle	124,15±5,47	122,94±5,66	***0,091***
SN-GoMe	36,00±7,07	34,10±6,87	***0,036****
FMA	27,02±6,67	26,83±6,91	***0,828***
SN-PP	9,57±3,54	8,15±3,31	***0,002*****
Gonial	124,74±7,35	123,74±7,65	***0,303***
OPT-NSL	105,93±8,47	101,36±8,92	***0,001*****

Student t test **p<0.05* ***p<0.01*

6.2.2. Evaluation of linear measurements and area for both sexes (Table 3)

S-N, Go-Me, Hy-C3i, Hy-Man Pl, and Oropharyngeal area measurements were found to be significantly lower for females ($p<0.01$) than males. However, Corrected PAS-UP, Corrected PAS-TP measurements were significantly higher for females than males (Table 3).

Table 3. Evaluation of linear measurements and area for both sexes

	Female (n=150)	**Male (n=100)**	
	Mean±SD	**Mean±SD**	*p*
S-N (mm)	66,61±4,29	71,20±4,21	***0,001*****
Go-Me (mm)	69,02±5,63	74,33±5,60	***0,001*****
Hy-C3i (mm)	32,89±3,45	37,04±3,66	***0,001*****
Hy-Mn Pl (mm)	14,28±5,09	16,80±5,77	***0,001*****
ad1 (mm)	18,35±4,02	19,30±3,93	***0,067***
PAS-UP (mm)	9,08±2,88	9,54±2,95	***0,216***
Corrected PAS-UP	13,26±2,18	12,08±2,30	***0,001*****
PAS-TP (mm)	9,99±3,35	10,00±3,61	***0,970***
Corrected PAS-TP	14,13±3,31	12,35±3,48	***0,001*****
Oropharyngeal Area (mm^2)	596,03±140,85	706,38±192,59	***0,001*****

Student t test ***$p<0.01$*

6.2.3. Correlation of variables with Saddle angle (Table 4)

When the correlation of variables with Saddle angle showed the same results for males (n=100) and females (n=150), the data was combined and the correlation of craniofacial variables with Saddle angle was evaluated for the whole sample group (n=250).

ANB and SN-PP ($p<0.01$) had high significant positive correlations with Saddle angle, on the other hand SNA, SNB, FMA had high significant negative correlations ($p<0.01$) (Table 4).

OPT-NSL also had positive correlation ($p<0.05$) whereas Hy-Mn Pl ($p<0.05$) had significant negative correlation with Saddle angle (Table 4).

Table 4. Correlation of variables with Saddle angle

	Saddle angle	
	r	***p***
Age	-0,059	***0,352***
SNA	-0,343	***0,001*****
SNB	-0,417	***0,001*****
ANB	0,176	***0,005*****
SN-GoMe	0,079	***0,213***
FMA	-0,167	***0,008*****
SN-PP	0,304	***0,001*****
Gonial	-0,085	***0,180***
OPT-NSL	0,129	***0,042****
S-N (mm)	-0,080	***0,208***
Go-Me (mm)	-0,069	***0,280***
Hy-C3i (mm)	-0,060	***0,347***
Hy-Mn Pl (mm)	-0,148	***0,019****
ad1 (mm)	-0,017	***0,794***
Oropharyngeal Area (mm^2)	-0,083	***0,189***

Pearson correlation analysis * $p<0.05$ ** $p<0.01$

6.2.4. Correlation of PAS-UP and Corrected PAS-UP with other variables in females (Table 5)

When the craniofacial measurements were correlated with PAS-UP, SNB, Go-Me, Hy-C3i and Oropharyngeal area measurements were found to be positively correlated with PAS-UP ($p<0.01$). The positive correlation ratios were 26.4%, 22.2%, 5.7%, 76.4%, respectively. On the other hand Hy-Mn Pl ($p<0.01$) and ANB ($p<0.05$) measurements showed significant negative correlations with 23.4% and 19.5% ratios, respectively (Table 5).

When the craniofacial measurements were corralated with Corrected PAS-UP, ANB, SN-GoMe, FMA and OPT-NSL were stated as positively correlated with the Corrected PAS-UP ($p<0.01$), their correlation ratios were 31%, 33.6%, 27.1% and 100% respectively. However, SNA, SNB, S-N, Go-Me and ad1 were found to be highly and negatively correlated with Corrected PAS-UP ($p<0.01$). 21.1%, 41.8%, 31.8%, 42.2%, 23.5% values were their correlation ratios, respectively (Table 5).

Table 5. Correlation of PAS-UP and Corrected PAS-UP with other variables in females

	PAS-UP		**Corrected PAS-UP**	
	r	***p***	**r**	***p***
Age	0,037	***0,651***	-0,127	***0,123***
SNA	0,136	***0,098***	-0,211	***0,009*****
SNB	0,264	***0,001*****	-0,418	***0,001*****
ANB	-0,195	***0,017****	0,310	***0,001*****
Saddle angle	0,114	***0,164***	0,076	***0,353***
SN-GoMe	-0,032	***0,700***	0,336	***0,001*****
FMA	-0,019	***0,822***	0,271	***0,001*****
SN-PP	-0,019	***0,818***	0,112	***0,173***
Gonial	0,019	***0,819***	0,028	***0,730***
OPT-NSL	-0,048	***0,562***	1,000	***0,001*****
S-N (mm)	0,012	***0,880***	-0,318	***0,001*****
Go-Me (mm)	0,222	***0,006*****	-0,423	***0,001*****
Hy-C3i (mm)	0,257	***0,001*****	-0,013	***0,878***
Hy-Mn Pl (mm)	-0,234	***0,004*****	0,117	***0,153***
ad1 (mm)	0,132	***0,106***	-0,235	***0,004*****
Oropharyngeal Area (mm^2)	0,764	***0,001*****	-0,078	***0,342***

Pearson correlation analysis * $p<0.05$ ** $p<0.01$

6.2.5. Correlation of PAS-TP and Corrected PAS-TP with other variables in females (Table 6)

When the craniofacial measurements were correlated with PAS-TP it was found that SNB (25.2%, $p<0.01$), Hy-C3i (45.6%, $p<0.01$) and Oropharyngeal area (69.5%, $p<0.01$), SNA (18.5%, $p<0.05$), OPT/NSL (20.8%, $p<0.05$), Go-Me (18, $p<0.05$) measurements were significantly positively correlated with PAS-TP, whereas Hy-Mn Pl showed significant negative correlation (24.3%, $p<0.01$) (Table 6).

When the craniofacial measurements were correlated with Corrected PAS-TP, ANB, OPT-NSL, FMA and SN-GoMe were stated as highly and positively correlated with Corrected PAS-TP ($p<0.01$). Their correlation ratios were 30.9%, 100%, 27%, 33.6%, respectively. However, SNA, SNB, S-N, Go-Me and ad1 measurements were found to be negatively correlated with 21.2%, 41.7%, 31.7%, 42.1%, 23.3% ratios respectively ($p<0.01$) (Table 6).

Table 6. Correlation of PAS-TP and Corrected PAS-TP with other variables in females

	PAS-TP		**Corrected PAS-TP**	
	r	***p***	**r**	***p***
Age	-0,014	***0,866***	-0,128	***0,117***
SNA	0,185	***0,023****	-0,212	***0,009*****
SNB	0,252	***0,002*****	-0,417	***0,001*****
ANB	-0,127	***0,121***	0,309	***0,001*****
Saddle angle	0,089	***0,280***	0,078	***0,344***
SN-GoMe	-0,110	***0,181***	0,336	***0,001*****
FMA	-0,087	***0,291***	0,270	***0,001*****
SN-PP	-0,093	***0,258***	0,110	***0,179***
Gonial	-0,038	***0,647***	0,028	***0,732***
OPT-NSL	0,208	***0,011****	1,000	***0,001*****
S-N (mm)	-0,028	***0,735***	-0,317	***0,001*****
Go-Me (mm)	0,180	***0,027****	-0,421	***0,001*****
Hy-C3i (mm)	0,456	***0,001*****	-0,013	***0,877***
Hy-Mn Pl (mm)	-0,243	***0,003*****	0,117	***0,155***
ad1 (mm)	0,025	***0,761***	-0,233	***0,004*****
Oropharyngeal Area (mm^2)	0,695	***0.001*****	-0.078	***0,344***

Pearson correlation analysis * *p<0.05* ** *p<0.01*

6.2.6. Correlations of variables with PAS-UP and Corrected PAS-UP in males (Table 7)

When the craniofacial measurements were correlated with PAS-UP, Oropharyngeal area (80.1%, p<0.01), Go-Me (26.0%, p<0.01) and SNB (29.6%, p<0.01) measurements were found to have significant positive correlations with PAS-UP. However, Age (21.5%, p<0.05), ANB (26.7%, p<0.01) had significant negative correlations with PAS-UP (p<0.01) When the craniofacial measurements were correlated with Corrected PAS-UP, SNA (45.2%, p<0.01), SNB (52.2%, p<0.01), S-N (32.7%, p<0.01), Go-Me (29, p<0.01), ad1 (27.3%, p<0.01) HyC3i (20.9%, p<0.05) measurements were found to have significant negative correlations with Corrected PAS-UP (Table 7).

SN-GoMe (40.1%, p<0.01), OPT-NSL (100, p<0.01), ANB (20.4%, p<0.01) and FMA (20.6%, p<0.05) showed significant positive correlations with Corrected PAS-UP (Table 7).

Table 7. Correlations of variables with PAS-UP and Corrected PAS-UP in males

	PAS-UP		**Corrected PAS-UP**	
	r	***p***	**r**	***p***
Age	-0,215	***0,032****	-0,005	***0,964***
SNA	0,124	***0,219***	-0,452	***0,001*****
SNB	0,296	***0,003*****	-0,522	***0,001*****
ANB	-0,267	***0,007*****	0,204	***0,042****
Saddle angle	-0,014	***0,892***	0,145	***0,150***
SN-GoMe	-0,086	***0,395***	0,401	***0,001*****
FMA	-0,082	***0,415***	0,206	***0,040****
SN-PP	0,008	***0,938***	0,180	***0,074***
Gonial	0,049	***0,625***	-0,005	***0,962***
OPT-NSL	-0,022	***0,827***	1,000	***0,001*****
S-N (mm)	0,155	***0,125***	-0,327	***0,001*****
Go-Me (mm)	0,260	***0,009*****	-0,290	***0,003*****
Hy-C3i (mm)	0,128	***0,203***	-0,209	***0,037****
Hy-Mn Pl (mm)	-0,042	***0,679***	0,175	***0,081***
ad1 (mm)	0,218	***0,029****	-0,273	***0,006*****
Oropharyngeal Area (mm^2)	0,801	***0,001*****	-0,097	***0,339***

Pearson correlation analysis **p<0.05* ***p<0.01*

6.2.7. Correlation of variables with PAS-TP and Corrected PAS-TP in males (Table 8)

SNB (22.6%, p<0.05), Go-Me (21.6%, p<0.05), Oropharyngeal area (60.4%, p<0.01) measurements showed significant positive correlations with PAS-TP. Age (22.4%, p<0.05), SN-GoMe (21.8%, p<0.05) showed significant negative correlations with PAS-TP (Table 8).

The parameters SNA (45.2%, p<0.01), SNB (52.2%, p<0.01), S-N (32.6%, p<0.01), Go-Me (28.9%, p<0.01), ad1 (27.3%, p<0.01), Hy-C3i (20.7%, p<0.05) had significant negative correlations with the Corrected PAS-TP. ANB (20.3%, p<0.05), FMA (20.6%, p<0.05), SN-GoMe (40.1%, p<0.01) and OPT-NSL (100%, p<0.01) showed positive significant correlations with Corrected PAS-TP (Table 8).

Table 8. Correlation of variables with PAS-TP and Corrected PAS-TP in males

	PAS-TP		**Corrected PAS-TP**	
	r	***p***	**r**	***p***
Age	-0,224	***0,025****	-0,003	***0,978***
SNA	0,130	***0,199***	-0,452	***0,001*****
SNB	0,226	***0,024****	-0,522	***0,001*****
ANB	-0,163	***0,104***	0,203	***0,042****
Saddle angle	0,097	***0,337***	0,143	***0,154***
SN-GoMe	-0,218	***0,029****	0,401	***0,001*****
FMA	-0,179	***0,074***	0,206	***0,040****
SN-PP	0,079	***0,437***	0,174	***0,083***
Gonial	-0,085	***0,398***	-0,005	***0,959***
OPT-NSL	0,143	***0,156***	1,000	***0,001*****
S-N (mm)	0,072	***0,478***	-0,326	***0,001*****
Go-Me (mm)	0,216	***0,031****	-0,289	***0,003*****
Hy-C3i (mm)	0,132	***0,189***	-0,207	***0,039****
Hy-Mn Pl (mm)	-0,113	***0,264***	0,177	***0,078***
ad1 (mm)	0,098	***0,330***	-0,273	***0,006*****
Oropharyngeal Area (mm^2)	0,604	***0,001*****	-0,095	***0,345***

Pearson correlation analysis ** p<0.05* *** p<0.01*

6.2.8. Evaluation of PAS-UP Corrected PAS-UP PAS-TP Corrected PAS-TP and Saddle angle according to vertical skeletal pattern in females (Table 9)

No intergroup differences were found for PAS-UP, PAS-TP, Saddle angle measurements among three different growth pattern groups (Low Angle n=6, High Angle n=60, Normal n=184) (p>0.05) (Table 9).

However, Corrected PAS-UP and Corrected PAS-TP measurements showed significant intergroup differences among three groups (p<0.01) (Table 9).

Corrected PAS-UP and Corrected PAS-TP measurements were found to be significantly higher in the high angle vertical growth pattern group than the measurements of the low (p<0.05) angle vertical growth pattern and normal (p<0.01) vertical growth pattern groups (Table 9).

No significant statistical difference was observed in the Corrected PAS-UP and Corrected PAS-TP measurements when groups of low angle vertical growth pattern and normal vertical growth pattern patients were compared (p>0.05) (Table 9).

Table 9. Evaluation of PAS-UP, Corrected PAS-UP, PAS-TP, Corrected PAS-TP and Saddle angle according to vertical skeletal pattern in females

Females	**Vertical**			***p***
	Low	**Normal**	**High**	
	Mean±SD	**Mean±SD**	**Mean±SD**	
PAS-UP	8,55±2,27	9,30±3,02	8,73±2,69	***0,457***
Corrected PAS-UP	11,67±2,42	13,08±2,16	14,21±1,77	***0,001*****
PAS-TP	9,32±3,16	10,36±3,30	9,34±3,48	***0,199***
Corrected PAS-TP	11,72±3,66	13,85±3,27	15,56±2,68	***0,001*****
Saddle angle	125,15±6,29	123,63±5,29	125,08±5,58	***0,286***

Oneway ANOVA test ***p<0.01*

6.2.9. Evaluation of PAS-UP Corrected PAS-UP PAS-TP Corrected PAS-TP and Saddle angle according to vertical skeletal pattern in males (Table 10)

PAS-UP, Corrected PAS-UP, PAS-TP, Corrected PAS-TP and Saddle angle measurements were compared among three different vertical growth pattern groups (Group1: Low Angle Vertical Growth Pattern, Group2: Normal Vertical Growth Pattern, Group3: High Angle Vertical Growth Pattern) (Table 10).

No intergroup differences were found for the PAS-UP, PAS-TP and Saddle angle measurements (p>0.05) (Table 10).

Significant intergroup differences were found for Corrected PAS-UP and Corrected PAS-TP measurements (p<0.05) (Table 10).

Corrected PAS-UP and Corrected PAS-TP measurements were found to be significantly higher in the high angle vertical growth pattern group than the low angle vertical growth pattern and normal vertical growth pattern groups (p<0.05) (Table 10).

No significant statistical difference was observed in the Corrected PAS-UP and Corrected PAS-TP measurements when groups of low angle vertical growth pattern and normal vertical growth pattern patients were compared (p>0.05) (Table 10).

Table 10. Evaluation of PAS-UP, Corrected PAS-UP, PAS-TP, Corrected PAS-TP and Saddle Angle according to vertical skeletal pattern in males

Males	**Vertical**			***p***
	Low	**Normal**	**High**	
	Mean±SD	**Mean±SD**	**Mean±SD**	
PAS-UP	9,50±2,66	9,58±3,17	9,42±2,25	***0,977***
Corrected PAS-UP	10,67±1,67	12,01±2,30	12,96±2,22	***0,049****
PAS-TP	11,32±2,82	9,92±3,77	9,79±3,30	***0,561***
Corrected PAS-TP	10,21±2,51	12,24±3,49	13,68±3,37	***0,048****
Saddle angle	122,12±4,05	122,80±5,57	123,81±6,69	***0,722***

Oneway ANOVA test *$p<0.05$

6.3. Lateral Cephalometric Evaluation by Elimination of Radiographs with FH -True Horizontal Angle >10°

On the second part of the study, based on previous literature (50, 123), the cases whose Frankfort Horizontal-true horizontal angle is more than 10° were eliminated. On these patients (n=227) Oropharyngeal area, and ad1 (nasopharyngeal distance) measurements were correlated with the cephalometric variables.

6.3.1. Correlation of variables with ad1 and Oropharyngeal area (Table 11)

SNA, SNB, S-N, Go-Me, Hy-C3i, PAS-UP measurements showed high positive correlations with ad1 ($p<0.01$) having correlation ratios of 18.3%, 19.3%, 36.3%, 37.8%, 27.7%, 17.6%, respectively. On the other hand SN-GoMe, SN-PP, OPT-NSL, Corrected PAS-UP, Corrected PAS-TP had high negative correlations ($p<0.01$) with 21%, 22.4%, 25%, 25.1% correlation ratios, Hy-Mn Pl measurement also showed significant negative correlation with p value of <0.05 (25%) (Table 11).

SNB (27.2%, $p<0.01$), S-N (31.5%, $p<0.01$), Go-Me (41.6% $p<0.01$), Hy-C3i (37.8%, $p<0.01$), PAS-UP (77.8%, $p<0.01$) and PAS-TP (65.2%, $p<0.01$) had highly significant positive correlations with Oropharyngeal area (Table 11).

ANB measurement showed high significant negative correlation with Oropharyngeal area (21.3%, $p<0.01$). In addition SN-Go-Me measurement also showed significant negative correlation with Oropharyngeal area (15%, $p<0.05$) (Table 11).

Table 11. Correlation of variables with ad1 and Oropharyngeal area

	ad1		**Oropharyngeal Area**	
	r	***p***	**r**	***p***
Age	0,050	***0,450***	-0,110	***0,097***
SNA	0,183	***0,006*****	0,127	***0,056***
SNB	0,193	***0,003*****	0,272	***0,001*****
ANB	-0,046	***0,493***	-0,213	***0,001*****
Saddle angle	-0,018	***0,788***	-0,052	***0,438***
SN-GoMe	-0,210	***0,001*****	-0,150	***0,023****
FMA	-0,123	***0,064***	-0,077	***0,246***
SN-PP	-0,224	***0,001*****	-0,002	***0,981***
Gonial	-0,129	***0,055***	-0,034	***0,608***
OPT-NSL	-0,250	***0,001*****	-0,125	***0,061***
S-N (mm)	0,363	***0,001*****	0,315	***0,001*****
Go-Me (mm)	0,378	***0,001*****	0,416	***0,001*****
Hy-C3i (mm)	0,277	***0,001*****	0,378	***0,001*****
Hy-Mn Pl (mm)	-0,161	***0,015****	0,083	***0,215***
PAS-UP (mm)	0,176	***0,008*****	0,778	***0,001*****
Corrected PAS-UP	-0,251	***0,001*****	-0,126	***0,058***
PAS-TP (mm)	0,076	***0,257***	0,652	***0,001*****
Corrected PAS-TP	-0,250	***0,001*****	-0,125	***0,060***

Pearson correlation analysis * $p<0.05$ ** $p<0.01$

6.3.2. Correlation of variables with ad1 and Oropharyngeal area in females (Table 12)

SN-PP (22.8%, p<0.01), OPT-NSL (22% , p<0.01), Corrected PAS-UP (22.2%, p<0.01) and Corrected PAS-TP (22%, p<0.01) had highly significant negative correlations with ad1 (Table12).

In addition to above, SN-GoMe (19.5%, p<0.05) and Hy-Mn Pl (19.3%, p<0.05) also had significant negative correlations with ad1 but the p values were found to be less than 0.05 (Table12).

The parameters S-N (38.7%, p<0.01), Go-Me (37.3%, p<0.01) and Hy-C3i (24.7%, p<0.01) had highly significant positive correlations with ad1 (Table12).

SNB (28.5%, p<0.01), Go-Me (29.4%, p<0.01), Hy-C3i (25.5%, p<0.01), PAS-UP (77.8%, p<0.01) and PAS-TP (69.6%, p<0.01) showed highly significant positive correlations with Oropharyngeal area but a negative statistical correlation was found between ANB and Oropharyngeal area (20.4%, p<0.05) (Table12).

Table 12. Correlation of variables with ad1 and Oropharyngeal area in females

	ad1		**Oropharngeal Area**	
	r	*p*	**r**	*p*
Age	0,082	***0,342***	-0,016	***0,849***
SNA	0,148	***0,084***	0,152	***0,077***
SNB	0,161	***0,060***	0,285	***0,001****
ANB	-0,048	***0,580***	-0,204	***0,017****
Saddle angle	-0,017	***0,844***	0,007	***0,936***
SN-GoMe	-0,195	***0,022****	-0,101	***0,238***
FMA	-0,137	***0,110***	-0,070	***0,414***
SN-PP	-0,228	***0,007****	0,053	***0,539***
Gonial	-0,111	***0,198***	-0,062	***0,468***
OPT-NSL	-0,220	***0,001****	-0,099	***0,252***
S-N (mm)	0,387	***0,001****	0,080	***0,351***
Go-Me (mm)	0,373	***0,001****	0,294	***0,001****
Hy-C3i (mm)	0,247	***0,004****	0,255	***0,003****
Hy-Mn Pl (mm)	-0,193	***0,024****	-0,064	***0,458***
PAS-UP (mm)	0,133	***0,122***	0,778	***0,001****
Corrected PAS-UP	-0,222	***0,009****	-0,098	***0,252***
PAS-TP (mm)	0,033	***0,698***	0,696	***0,001****
Corrected PAS-TP	-0,220	***0,001****	-0,098	***0,252***

Pearson correlation analysis * $p<0.05$ ** $p<0.01$

6.3.3. Correlation of variables with ad1 and Oropharyngeal area in males (Table 13)

S-N (30.1%, p<0.01), Go-Me (35.8%, p<0.01), Hy-C3i (27.1%, p<0.01), SNA (21.9%, p<0.05), SNB (22.5%, p<0.05) and PAS-UP (22.4%, p<0.05) showed significant positive correlations with ad1 (Table 13).

OPT/NSL (25.2%, p<0.05), Corrected PAS-UP (25.2%, p<0.05) and Corrected PAS-TP (25.2%, p<0.05) showed negative correlations with ad1 (Table 13).

Table 13. Correlation of variables with ad1 and Oropharyngeal area in males

	ad1		**Oropharngeal Area**	
	r	***p***	**r**	***p***
Age	0,005	***0,962***	-0,222	***0,035****
SNA	0,219	***0,038****	0,074	***0,491***
SNB	0,225	***0,033****	0,236	***0,025****
ANB	-0,032	***0,762***	-0,228	***0,030****
Saddle angle	0,004	***0,968***	-0,068	***0,527***
SN-GoMe	-0,203	***0,055***	-0,134	***0,209***
FMA	-0,096	***0,366***	-0,080	***0,454***
SN-PP	-0,179	***0,092***	0,053	***0,618***
Gonial	-0,136	***0,203***	0,058	***0,585***
OPT-NSL	-0,252	***0,017****	-0,019	***0,858***
S-N (mm)	0,301	***0,004*****	0,355	***0,001*****
Go-Me (mm)	0,358	***0,001*****	0,386	***0,001*****
Hy-C3i (mm)	0,271	***0,001*****	0,302	***0,004*****
Hy-Mn Pl (mm)	-0,183	***0,085***	0,114	***0,286***
PAS-UP (mm)	0,224	***0,034****	0,821	***0,001*****
Corrected PAS-UP	-0,252	***0,0017****	-0,021	***0,845***
PAS-TP (mm)	0,129	***0,225***	0,660	***0,001*****
Corrected PAS-TP	-0,252	***0,017****	-0,020	***0,850***

Pearson correlation analysis *$p<0.05$ **$p<0.01$

S-N (30.1%, $p<0.01$), Go-Me (35.8%, $p<0.01$), Hy-C3i (27.1%, $p<0.01$), PAS-UP (22.4%, $p<0.01$) and SNB (22.5% $p<0.01$) showed highly significant positive correlations with ad1 (Table 13).

Age (22.2%, $p<0.05$) and ANB (22.8%, $p<0.05$) showed significant negative correlations with Oropharyngeal area (Table 13).

7. DISCUSSION

Cephalometric radiography has become one of the most important tools in orthodontics both clinically and in research. It has been used extensively to quantify the dental, skeletal, and soft tissue relationships of the craniofacial complex, before the initiation of treatment and during growth. Less often, and usually in clinical research, cephalometry is used to asses craniocervical angulation, pharyngeal relationships, soft palate dimensions, and hyoid bone and tongue position (66). Recent advances in imaging and a variety of other investigative techniques have stimulated a spate of reports on the oropharyngeal airway, in particular: computerized tomography (CT), acoustic reflection, flouroscopy, fibro-optics, and magnetic resonance (MR). Despite these sophisticated methods, the lateral cephalometric radiograph is still commonly used in examining the oropharyngeal airway and other anatomic features (123).

Cephalometric radiography has been used extensively as a measurement tool for studying the posterior airway space and craniofacial morphology. CT and MR scans have also been used for this purpose. The validity of evaluating the posterior airway space, a three-dimensional structure, on the basis of two-dimensional cephalograms has been questioned. The position of patients for radiographic examination differs from that for CT or MR scans. Cephalometric studies are usually carried out with the patient in a standing or prone position, whereas for a CT or MR scan the patient is supine. Cephalometric analysis of the airway permits precise measurements in a sagittal plane at anatomically well-defined homologous locations. Although CT and MR scans can provide transverse, sagittal, and area measurements of airway dimensions, the results of different studies are difficult to compare owing to the lack of standardization of thickness, direction, and the precise location of the sections (113). It is evident that measurements on a two-dimensional cephalometric radiograph cannot reveal the transverse dimension of the airway. For this reason, three-dimensional imaging such as cone beam technology would be the preferred method. Since this technology was only introduced in recent years and has until now a relatively high radiation dose for regular treatment monitoring, no long-term data will be available for some time. Therefore, the conventional lateral cephalogram remains as a valuable and reliable diagnostic tool which has been used in numerous airway studies (47). This study was conducted with 2-dimensional headfilms to evaluate only pharyngeal airway widths, and not airway flow capacities, which would have required a more complex 3-dimensional and dynamic evaluation (78, 133). Therefore, the results of Freitas et al`s study (41) do not suggest that patients with vertical growth patterns have smaller airway flow capacities than those with normal growth patterns. Perhaps, vertical-growth patients are larger, transversely, than normal growers; this should be further investigated (78, 133). Cephalometry offers considerable advantages over other techniques, including low cost, convenience and minimal exposure to radiation, as well as being able to simultaneously analyze head position, hyoid position and craniofacial morphology.

We evaluated airway size by analyzing cephalograms. Although a cephalogram provides only a 2-dimensional image of the pharyngeal airway, it has been used extensively in the assessment of sleep apnea and craniofacial form (92). The advantages of a cephalometric analysis include its wide availability, simplicity, low expense, and ease of comparison with extensive normative data and other studies. Furthermore, good correlation between airway dimensions measured on lateral cepholmetric radiographs and on 3-dimensional computed tomography was reported (75) validating the usefulness of cephalograms in airway size analysis. All the cases were selected from the patients referred to Marmara University, Faculty of Dentistry, Department of Orthodontics for treatment. Because of the retrospective design of the study, a direct assessment of the nasorespiratory pattern of each patient was not possible. Therefore, based on clinical chart information selected patients were considered to have healthy pharyngeal functions. Evidently, this is not the ideal, however we expected that the pharyngeal widths would reflect only their natural anatomical conditions with no pharyngeal pathology. Since the cases of the study were drawn from patients with malocclusions, they might not be entirely representative of the population as a whole and some bias should be assumed.

The facial skeleton generally increases in size with growth, associations between cephalometric variables are usually due to common dependence on age. In the literature it was observed that the naso and oropharyngeal depth is formed in the early ages of life and then it usually remains the same (45, 63, 122). The nasopharyngeal dimensions continue to grow rapidly until 13 years of age and then slows until adulthood (45, 59, 122). In this study the age range was 16-19 years to ensure that the oropharyngeal structures had reached adult size. Therefore, the effect of age was minimized by restricting the age range to 16 to 19 years and by testing for correlation between age and posterior airway space measurements.

In the present study, lateral radiographs were taken by usual standardized method. However, craniocervical angulation (OPT/ NSL) still ranged from 79° to 126°. This wide range suggests that head position varies among individuals on radiographic examination. The study of Muto et al (84) showed that a change of 10° in craniocervical angulation leads to a change of about 4 mm in the posterior airway space. Similar associations between craniocervical angulation and the posterior airway space in normal subjects have been found in studies in which measurements were obtained when subjects had their heads positioned at different degrees of extension and flexion (92, 109). The effect of head extension on the posterior airway space may depend on the degree of extension. Previous studies in which the posterior airway space was radiographically measured, positioned patients so that the cephalogram was taken in a mirror position, a natural head position, or with a horizontal Frankfort plane, and the effects of craniocervical angulation on the posterior airway space were not considered (55, 69, 135). Besides the study of Muto et al (85), Trenouth (123) also has taken head posture into account when measuring the posterior airway space and the cephalograms which has a Frankfort horizontal plane more than 10° above the true horizontal plane were deleted to avoid bias. So efforts should be made to measure the posterior airway space more accurately.

When measuring the pharyngeal airway space head position should be considered since changes in this variable can affect the size of the pharyngeal airway space. In the present study the correlations of the craniofacial morphologic variables were examined with the measured and the corrected pharyngeal airway spaces as it is performed in the study of Muto et al (85).

Muto et al (85) cephalographically studied the relationship between the pharyngeal airway space and facial morphology in normal subjects, taking into account head posture. Head posture may vary although the orbital-auricular plane is maintained parallel to the floor, the craniocervical angulation (OPT/NSL) may not be constant. To minimize the effect of head posture on the pharyngeal airway space, the regression equations were formed and measurements were corrected in their previous study (84). According to the results of their study, the measured PAS-UP moderately correlated with 10 of 23 variables, whereas the Corrected PAS-UP correlated with only three variables (Uvula-L, Ar-Gn, and PNS-Ba). Thirteen variables correlated with the Corrected PAS-TP including hyoid position (Hy-C3), size of maxilla and mandible (MAX-L, Go-Gn, Ar-Gn, Ar-Go), maxillary and mandibular prognathism (SNA, SNB, SNP) and mandibular inclination (GZN, SN-MP, Fac-axis), S-Go, and PNS-Ba. In general subjects with a large and anteriorly positioned mandible was associated with a large PAS-TP. In our study the Corrected values do not reflect significant results for the sagittal evaluation of the maxillary and mandibular jaw relationships. The reason for this may be the subjects in the present study have malocclusions of all types whereas the study group of Muto et al consists of only the subjects with Class I malocclusion.

Because correlation with pharyngeal airway space may be due to the common dependence on age, it was important to eliminate this factor. For this reason, the cephalometric measurements were correlated with age. The age was found to be negatively correlated with PAS-UP, PAS-TP and Oropharyngeal area in males. So age may be a factor responsible for any correlations with pharyngeal airway space. In the study of Trenouth (123), none of the cephalometric variables showed any statistically significant correlation with age. This may be due to the mean age of the patients selected for the study and sample size of the study. He also evaluated the cephalometric variables' differences between males and females and stated that none of the cephalometric variables showed any statistically significant correlation with sex. However, in this study Cranial base angle, Hy-C3i and Go-Me measurements were found to be the only ones which did not show significant differences between two genders (123). Therefore, all the cephalometric evaluations were done on males and females seperately.

There is a true relationship between some of the cephalometric variables and pharyngeal airway space. As the body of mandible lengthens, the attachment of genioglossus and geniohyoid muscles move forward away from the pharyngeal airway space increasing the airway distance. Trenouth (123) reported that the oropharyngeal airway size was positively correlated with the length of mandible (Go-Me), the distance between the third cervical vertebra and the hyoid bone (Hy-C3i) and the cranial base angle (NSBa). In the present study, the Hy-C3i and Go-Me distances were found to be positively correlated with the pharyngeal airway space whereas there was no correlation with the Cranial base angle (NSAr).

Mandibular deficiency has been linked to reduced oropharyngeal airway dimensions. Decreased space between cervical column and mandibular corpus may lead to a posteriorly postured tongue and soft palate, increasing the chances of impaired nasal respiratory function during the day (39). Özbek et al (91) evaluated the use of functional orthopedic devices in increasing oropharyngeal airway dimensions in children with Class II skeletal patterns, their results clearly suggested the existance of a relationship between functional orthopedic treatment and an increase in oropharyngeal airway dimension in the study groups. The findings of Hänggi et al (47) also indicated that activator-headgear therapy (followed by fixed appliance treatment) has the potential to increase pharyngeal airway dimension. These two studies conclude that increases in the length of mandible and the SNB angle associate with the increase in the airway dimensions. Considering that cervical headgear does not exert orthopedic forces directly on the mandible, its effects on mandibular growth are intriguing. Graber (42) mentioned that reflective forward mandibular thrust was associated with cervical headgear therapy and that such "activatorlike" movement could be beneficial to mandibular growth. Hiyama et al (52) reported that the resting mandibular position moved anteriorly when awake subjects wore cervical headgear and suggested that Graber's hypothesis was valid under these conditions. Moreover, the change in mandibular position seemed to be related to the reduction in the upper airway dimension caused by the pressure on the back of the neck by the neck strap (52). Hiyama et al (53) examined, with the use of pairs of supine lateral cephalograms, the changes in mandibular position and oropharyngeal structures that are induced by wearing the cervical headgear. A significant reduction in the middle upper airway dimension was demonstrated by the wearing of cervical headgear during sleep. In addition, both the superior and inferior upper airway dimensions also tended to decrease by wearing cervical headgear. The reduction in the sagittal dimension of the upper airway by wearing cervical headgear during sleep may modify the respiratory function during sleep. The reason for the reduction in the middle upper airway may be due to the records taken all in supine positions and the lack of sagittal mandibular growth among the patients. On the other hand, Kirjavainen (64) studied the effects of cervical headgear treatment of Class II division 1 malocclusion on upper airway structures in children and concluded that Class II malocclusion is related to a narrower oro and hypopharyngeal spaces than in controls. Cervical headgear treatment increases retropalatal airway space but does not significantly affect the rest of the oropharynx or hypopharynx in children with Class II malocclusion. He also indicated that the ANB value decreased by means of sagittal mandibular growth. Therefore it may be evaluated as, if there is a sagittal mandibular displacement the airway shows an increase in dimension. In the present study SNB angle showed negative correlation with Corrected PAS-UP indicating similar result with the study of Kirjavainen (64).

Severe maxillary hypoplasia seen in craniofacial anomalies has been suggested to constrict the upper airway, including the nasal cavity and velopharynx (46, 57). The effects of a maxillary protraction appliance used in combination with a chin cap have been shown to alter the upper airway dimension during maxillary protraction (54). Considering that mandibular growth has a definite influence on the upper airway dimension, it can be speculated that maxillary growth could also have beneficial effects on the upper airway (54). Even though no significant changes between pre- and post-treatment airway parameters were found by Hiyama et al (54), they carried out a multiple regression analysis which revealed that greater forward maxillary growth was associated with a greater increase in the superior upper airway dimension. A possible explanation as to why Hiyama et al (54) could not find any differences in between the pre and post-treatment airway parameters may be the lack of related parameters in their study. The upper airway measurements used (SPPS, MPS, IPS) were mainly at the back of the tongue and very minimally related to maxillary structures. The backward rotation of the mandible, although implicitly restricted the related sagittal airway dimensions. Sayınsu et al (105) was in agreement with their findings of which there was an increase in nasopharyngeal airway measurements and a clockwise rotation of the mandible as revealed by the decrease in SNB angle, in addition the vertical parameters showed a statistically significant increase. They concluded that maxillary disarticulation and protraction improved naso- but not oropharyngeal airways like Hiyama et al (54). The reason for the only increase in nasopharyngeal but not in oropharyngeal dimensions may be due to protraction of maxilla is in conjunction with the downward and backward rotation of mandible in which its sagital growth is restricted. But the studies of Kılınç et al (62) and Oktay (88) indicated that a significant increase was observed in the post-treatment oropharyngeal dimensions which was most likely due to less mandibular posterior rotation and a smaller decrease in SNB. Because previous studies (54, 105) lacked control groups, they probably could not assess the amount of change in this area that would be expected from growth and development regardless of orthodontic treatment. In the present study SNA angle was the only indicator for the sagittal placement of maxilla and it had positive significant correlations with only PAS-TP values of females and ad1 values of all groups. So it is the similar result emphasizing nasopharyngeal airway dimension is in association with the protruded maxilla. On the other hand we found a correlation with PAS-TP value in females. The additional mandibular growth, the posture of tongue during the radiographic recording and the thickness and position of soft palate may be responsible of these results. In our study it is also shown that as the vertical pattern of the subjects increase, the nasopharyngeal airway dimension, Oropharyngeal area and PAS-TP values decrease which coincides with the studies of Hiyama et al (54) and Sayınsu et al (105).

Battagel et al (9) evaluated the alterations in airway and hyoid position in response to mandibular advancement in subjects with mild to moderate OSA. Pairs of supine lateral skull radiographs were obtained for the patients. As long as the radiographs were in supine position and the mandible was protruded by means of the mandibular advancement splints, vertical facial dimensions of the patients were increased as well as the SNB values. With respect to mandibular movement the hyoid mandibular plane distance decreased and the oropharyngeal area showed an improvement in value in both sexes. In our study PAS-UP, PAS-TP and

Oropharyngeal area values displayed highly positive correlations with SNB angle, showing that when the mandible is placed in a more protruded position in relation to the cranial base the airway becomes larger.

Several studies attempted to investigate the effect of orthognathic surgery on the posterior airway space in patients with Class III deformities (20, 33, 102, 125). Most of these studies investigated only the effects of mandibular setback surgery for the correction of the mandibular prognathism and lateral cephalometric radiographs were used as resources to investigate the structures of the pharyngeal airway. There are only a few reports evaluating the effects of bimaxillary surgery for correcting Class III skeletal deformities on posterior airway space and all of them used lateral cephalometric radiographs (20, 79, 128). It is reported that counterclockwise rotation of the maxillomandibular complex significantly affects the postsurgical posterior airway space dimension in patients with high occlusal plane facial morphology. Increase in pharyngeal airway space at the soft palate and at the base of the tongue are related to the amount of mandibular advancement whereas decrease in pharyngeal airway space at the soft palate and at the base of the tongue are related to the amount of mandibular setback (79). In several studies it has been indicated that the pharyngeal airway was constricted significantly at the oropharyngeal and hypopharyngeal levels at both the short-term and the long-term follow-ups in the patients who underwent bilateral sagittal split ramus osteotomies and significant changes were shown at the 3 pharyngeal levels at the short-term follow-up in the patients who underwent LeFort I procedures with bilateral sagittal split ramus osteotomies indicating that, when possible, bimaxillary surgery rather than only mandibular setback surgery is preferable to correct a Class III deformity to prevent narrowing of the pharyngeal airway space, a possible predisposing factor in the development of obstructive sleep apnea (20, 27, 55, 102, 103, 124).

The oropharyngeal airway space was measured and it showed negative correlations with ANB and SN-GoMe. In Ceylan et al's study (18), it was shown that the oropharyngeal airway space was affected by the ANB angle, and two other sagittal airway dimensions (t-ppw; distance between the dorsal tongue surface and posterior pharyngeal wall intersecting occlusal plane, hy-apw2; the distance between the hyoid and anterior pharyngeal wall along line intersecting cv2ia and hy) which are not coinciding with the sagittal airway dimension levels in our study. Even the mean age of the study groups in their and our studies are different (younger in Ceylan et al's study and older in ours), the samples used in both of the studies consisted of subjects older than 13, so the sagittal measurements are more stable compared with other groups.

Because posture has a significant effect on upper airway dimensions the use of supine, rather than the traditional upright radiographs has been recommended (74, 82, 134). However this technique is less commonly reported (76, 94, 95, 96, 134). Eveloff et al (37) and Lowe et al (75) have indicated that the use of supine films is a satisfactory method of demonstrating the airway changes in patients with mandibular advancement splints in place, but the method does not appear to have been used in a diagnostic capacity.

In the study of Solow et al (110) the correlations between the variables screening craniofacial morphology and airway revealed an interesting pattern of associations. Airway adequacy was related to the size and position of the mandible as it is in the present study, but no associations were found with the corresponding maxillary variables. It should be considered that the sample of their study had only 24 subjects and the mean age was only 8,6 years. It is important to notice that correlation analysis alone does not indicate the nature of causal mechanisms at work. The radiographic measure of airway showed marked correlations with the craniocervical angulation. A small airway distance seen in connection with a large craniocervical angle whereas a large airway distance was seen in connection with a small craniocervical angulation. Our finding evaluating the association between the craniocervical inclination and airway (ad1) was parallel to the findings of Solow et al. There was a highly negative correlation between the OPT/NSL angle and ad1 in our sample.

In adults, the site of airway occlusion, during apneic episodes in OSA, is usually located in the oropharyngeal region, involving the soft palate, the dorsum of the tongue and the posterior pharyngeal wall (113). Solow described the antero-posterior airway diameters in erect awake OSA patients and a reference sample and examined whether a relationship could be found in these patients and in the reference sample between the cranio-cervical angulation and the pharyngeal airway. In the OSA sample, the correlations between airway diameters and head posture showed a systematic pattern of significant associations indicating that on average, a narrow airway diameter at the rl-prl (which is PAS-TP in the present study) was seen in connection with a large cranio-cervical angle. In the reference sample who are young adults, no associations were found between the postural angles and the diameters behind the soft palate or the root of the tongue. The littleness of correlations in the reference sample in comparison with the OSA sample is probably also related to the fact that the craniocervical postural angles in the reference sample were located at a much lower range (OPT/NSL: 73-105 degrees), than those in the OSA sample (89-131 degrees) (108, 112). Obviously a large increase in cranio-cervical angulation is required in order to produce an increase in the airway diameters at the levels of the soft palate and the base of the tongue, the sites where OSA obstructions most often occur. Hellsing (50) also studied the changes in the relationship between the position of the hyoid bone, the size of crosssections of the pharyngeal airway and the curvature of the cervical spine with varying head postures and concluded that the subjects with their head extended 20° showed increase in the craniocervical inclination and in the size of the lower pharyngeal airway. These findings could be compared with a study on children, where Solow et al (110) found a negative correlation between airway obstruction and a large craniocervical inclination possibly creating a narrower airway passage at the level of the hyoid bone. This conclusion is also in agreement with the conclusion of Muto et al (84). In our study PAS-UP values both in males and females did not show any correlations with the craniocervical angle like Solow et al's study (113) and its reference sample, on the other hand the value of PAS-TP of females showed positive correlations with OPT/NSL.

Head posture is in association with vertical growth pattern of an individual (41). In relation with this statement, in the present study, the airway distance values that are corrected according to the head postures showed correlations with the vertical growth patterns of the subjects. Although brachycephalic patients were found to be more prone to pharyngeal constriction because of their head form with shorter anterior-posterior dimensions of the cranial base, reduced middle cranial fossa, and reduced upper airway anterior-posterior dimension (36, 120), it has been reported that patients with vertical growth patterns had significantly narrower upper pharyngeal airways than subjects with normal growth pattern (1, 29). In the present study the difference between measured PAS-UP and PAS-TP values of the groups with different vertical skeletal growth patterns was found statistically insignificant. On the other hand the cases with high angle skeletal growth patterns had higher Corrected PAS-UP and Corrected PAS-TP values than the ones with normal ($p=0.001$; $p<0.01$) and low angle ($p=0.001$; $p<0.01$) skeletal growth patterns. Analyzing these results, we can conclude that upper airway width is influenced by the craniofacial growth pattern. Freitas et al (41) stated subjects with vertical growth patterns had significantly narrower upper pharyngeal airways than Class I and Class II subjects with normal growth patterns, confirming previous results in the literature, however they found no statistically significant difference in lower pharyngeal airways between groups, showing no association of lower pharyngeal airway space with craniofacial growth pattern and malocclusion type (29, 99). This corroborates previous studies (18, 45, 116). In our study Corrected PAS-UP and Corrected PAS-TP values were in correlation with vertical growth pattern, but emphasizing larger pharyngeal airways. This difference from the study Freitas et al's may be due to the fact that there was correlation only with measured values in their study not with the corrected ones. Muto et al (84) found that Corrected PAS-TP showed moderate negative correlation with SN-Man Pl angle which is in contradiction with the result of the present study. This may be due to the fact that the subjects of Muto et al's study had Class I malocclusions whereas the patients in the present study have malocclusions of all types.

8. CONCLUSIONS

1. The age was found to be negatively correlated with PAS-UP, PAS-TP and Oropharyngeal area in males.
2. The Hy-C3i and Go-Me distances were found to be positively correlated with the pharyngeal airway space whereas there was no correlation with the Cranial base angle (NSAr).
3. The oropharyngeal airway distances and area are positively correlated with length of mandible.
4. The nasopharyngeal airway (ad1) is in positive correlation with the sagittal maxillary position.
5. The craniocervical inclination was only associated with the nasopharyngeal airway (ad1).
6. PAS-UP distance was positively correlated with 3rd cervical vertebrae and hyoid bone.
7. Corrected PAS-UP and Corrected PAS-TP values were in correlation with high angle skeletal growth pattern, emphasizing larger pharyngeal airways.

Further studies may be needed to evaluate the morphologic changes in the pharyngeal airway space by 3-dimensional (3D) imaging techniques in order to bring out more clear observations.

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10. BIOGRAPHY

Kişisel Bilgiler

Adı	İrem	**Soyadı**	Soydaş
Doğum Yeri	İstanbul	**Doğum Tarihi**	12/04/1979
Uyruğu	T.C.	**TC Kimlik No**	41644519374
E-mail	iremsoydas@yahoo.com	**Tel**	0532 201 74 77

Eğitim Düzeyi

	Mezun Olduğu Kurumun Adı	**Mezuniyet Yılı**
Doktora/Uzmanlık	M.Ü. Diş Hekimliği Fakültesi, Ortodonti Anabilim Dalı	2009
Yüksek Lisans	M.Ü. Diş Hekimliği Fakültesi	2002
Lisans	-	
Lise	Özel Üsküdar Fen Lisesi	1997

İş Deneyimi (Sondan geçmişe doğru sıralayın)

	Görevi	**Kurum**	**Süre (Yıl - Yıl)**
1.			-
2.			-
3.			-

Yabancı Dilleri	**Okuduğunu Anlama***	**Konuşma***	**Yazma***
İngilizce	Çok iyi	Çok iyi	Çok iyi

* Çok iyi, iyi, orta, zayıf olarak değerlendirin

Yabancı Dil Sınav Notu #								
KPDS	ÜDS	IELTS	TOEFL IBT	TOEFL PBT	TOEFL CBT	FCE	CAE	CPE
70	-	-	-	-	597	-	-	-

* Başarılmış birden fazla sınav varsa, tüm sonuçlar yazılmalıdır

	Sayısal	**Eşit Ağırlık**	**Sözel**
LES Puanı	65	63	61
(Diğer) Puanı			

Bilgisayar Bilgisi

Program	**Kullanma becerisi**
Windows XP home	Çok iyi
Office 2003	Çok iyi

*Çok iyi, iyi, orta, zayıf olarak değerlendirin

Uluslararası ve Ulusal Yayınları/Bildirileri/Sertifikaları/Ödülleri/Diğer