ORIGINAL ARTICLE

KOREA. J. ORTHOD. 1995. 25(6) : 655-664

CEPHALOMETRIC STUDY OF OBSTRUCTIVE SLEEP APNEA PATIENTS IN THE UPRIGHT AND SUPINE POSITIONS

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Sixty male patients with polysomnographically documented OSA were included in this study. A pair of cephalograms were obtained in the upright and supine positions. In the supine position, the ANB angle, lower facial height and the cross-sectional area of soft palate increased and there was a decrease in the vertical airway length and oropharynx cross-sectional area. Positional changes did not affect the cross-sectional area of tongue, but the cross-sectional area of the oropharynx decreased in the supine position.

The obese group had higher AI and RDI. Maxillary unit length, C3-H, the cross-sectional areas of tongue, soft palate and oropharynx were significantly greater in the group Obese than in non-obese group. No correlation was noted between the mandibular unit length and OSA severity, The group of small mandibular unit length showed shorter lower facial height and maxillary unit length, and smaller cross-sectional area of tongue than the long mandibular unit length group. Hyold bone positioned more inferiorly and cross-sectional area of nasopharynx decreased as the OSA severity increased.

Key words : Cephalometry, Sleep apnea, Positional change, Obesity, Mandibular unit length, Apnea severity

Guilleminault et al[1] first reported sleep apnea syndrome in 1973. Obstructive sleep apnea (OSA) is a failure of breathing during sleep, brought about by the obstruction of the upper airway despite the persistent respiratory efforts[2]. Patients with this syndrome breathe normally during the waking hours, but have difficulty in breathing during sleep. Their symptoms are loud snoring, excessive daytime sleepiness and fatigue, changes in personality, sexual dysfunction, nocturnal enuresis, morning headache and reduction of mental efficiency[3-8]. The usual reason patients seek treatment is daytime hypersomnolence as a result of inadequate night-time sleep. A number of anatomical malformations have been reported in OSA patient such as micrognathia[9], retrognathia[10], adenotonsillar hypertrophy[11], macroglossia[12], elongated soft palate[13-14], decreased posterior airway space and improper position of the hyoid bone.

Obesity is known as the most significant risk factor for OSA[16]. Other risk factors are male gender, aged between 40 and 65 years, cigarette smoking and use of alcohol[17]. The upper airway could be changed with positions related to the effects of gravity of upper airway structures and to the lung volume dependence of upper airway patency.

Many studies have assessed the upper airway in OSA patients by various technique including cephalometry[18-27], computed tomography[28-32], fluoroscopy[33], magnetic resonance imaging[14] and acoustic reflectance[34]. The major advantages of cephalometry are easy access, low cost and minimal radiation[35]. Though cephalometry is a two dimensional assessment, there is a good correlation between the posterior airway and the pharyngeal space measured by cephalometric and computerized tomography[32].

The treatment of OSA depends on the severity of symptoms, the magnitude of clinical complications and the etiology of the upper airway obstruction[36]. There are many methods of OSA treatment including weight reduction, avoidance of alcohol, use of dental appliances, continuous positive airway pressure(CPAP), pharmacotherapy and surgery(uvulopalatopharyngoplasty, tracheotomy, mandibular advancement surgery)[37-46]. Knowledge of the distribution and severity of structural abnormalities is of clinical importance relevant to planning therapy.

The purpose of this study was to investigate the predisposing factors in OSA patients. The craniofacial morphology, tongue and airway were examined as the patients were subjected to upright and supine positions. The data were compared between the positional changes, between obese and non-obese patients, between the patients with small and large mandibular unit lengths and according to the severity of the symptoms.

MATERIALS AND METHODS

A. Experimental subjects

88 patients(77 male, 11 female) were examined from sleep clinic in U.B.C. hospital. They all complained of snoring and most of them had other complaints suggesting sleep apnea. Patients with respiratory infection, edentulous patients or those who need orthognathic surgery were not included. Six patients were disregarded because they did not have BMI, AI or RMI recordings. Among the remaining 82 patients, 9 patients were female and 73 patients were male.

The severity of the sleep apnea was evaluated by a combination of apnea index(AI), defined as the total number of apneas devide by the total sleep time in minutes, and respiratory disturbance index(RDI) defined as the total number of apneas and hyponeas divided by the total sleep time in minutes. Patients with AI lower than 5 or RDI lower than 10 were also disregarded. Since only three were female among the remaining 63 symptomatic patients, they were again excluded to make a homogeneous group. The overnight polysomnographic study was carried out at the respiratory sleep disorder clinic and sleep study data were used in this study.

Patients were divided into three groups according to the severity of their symptoms, i.e., mild, moderate and severe groups. The average age of the patients was 45.25 years ranging from 19 to 69 years. Average BMI(Body Mass Index=wt(kg)÷ht(m)^2) was 30.16(range : 21.9 to 50.4), AI 17.27(range : 0.6 to 77.3), and RDI 40.33(range 5.9 to 99.0)(Table 1).

Table 1. Sample description (N=60)

Variables	Mean	S. D.	Range
AGE	45.25	(11.25)	19-69
BMI	30.16	(5.52)	21.9-50.4
AI	17.27	(18.85)	0.6-77.3
RDI	40.33	(23.98)	5.9-99.0

B. Methods

1) Cephalometric study

Individual cephalograms were taken with the conventional method(165cm source-target distance, 14cm film target distance, 90kvp, 15mA, 1.25sec) in the upright and supine positions. To obtain the upright lateral cephalogram, natural head posture was determined by visual feedback in a mirror. For the supine cephalogram, the subject was instructed to lie down on a stretcher and to take his usual sleeping position with comfortable pillow height. The supine lateral cephalogram was taken with the jaw completely relaxed. The cephalograms were taken in the instructed position at the end of expiration with the head fixed by ear-rods.

2) Description of landmarks and linear, angular and cross-sectional measurements(Figure 1).

The anatomic landmarks, linear, angular and cross-sectional measurements used in this, study are as follows.

<<u>*ANATOMIC LANDMARKS*</u>>

S sella : The estimated center of the sella turcica.

N Nasion : The most anterior point of the naso-frontal suture.

A A point Subspinale : The deepest point on the anterior surface of the mandibular symphysis.

Me Menton : The most interior point on the mandibular symphysis

RGN Retrognathion : The most posterior point of the

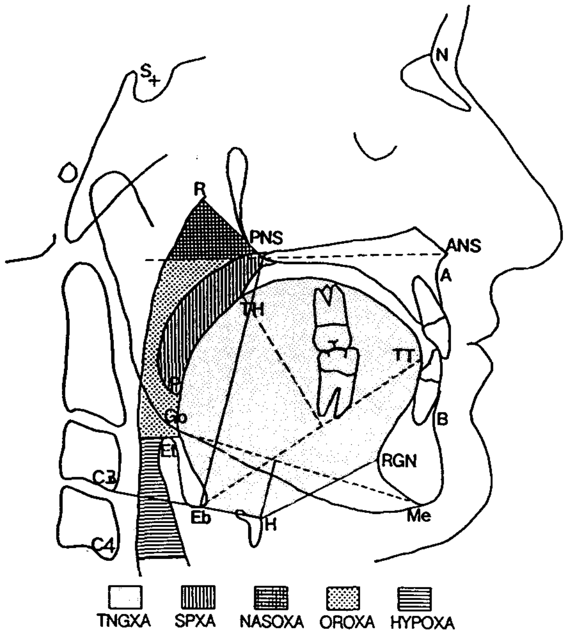

Figure 1. Cephalometric landmarks, linear and cross-sectional measurements.

mandibular symphysis along a line perpendicular to the FH(Frankfort Horizontal) plane.

C3 Third Vertebra : The most anterior inferior point of the third vertebral corpus.

C4 Fourth vertebra : The most anterior inferior point of the fourth vertebral corpus.

TT Tongue Tip : The most anterior point of tongue between the ventral and dorsal surfaces of the tongue tip.

TH Tongue Height : The highest point of the tongue curvature relative to a line from base of the epiglottis to TT.

Eb Base of Epiglottis : The deepest point of the epiglottis.

Et Tip of Epiglottis : The most superior point of the epiglottis.

H Hyoidale : The most anterior and superior point of the hyoid bone.

ANS Anterior nasal spine : The apex of the anterior nasal spine.

PNS Posterior nasal spine : The apex of the posterior nasal spine of the palatal bone.

R Roof of the pharynx : The point on the posterior pharyngeal wall constructed by a line PNS to the cross-sectional point of the cranial base and the lateral pterygoid plate.

P Palate point : The most inferior tip of the soft tissue.

<*LINEAR, ANGULAR and AREA MEASUREMENTS*>

ANB(°) : Difference between SNA and SNB.

LFH(mm) : Lower Facial Height : The linear distance between the point obtained by projecting ANS along a perpendicular to the nasion-menton line and menton.

MxUL(mm) : The linear distance from the midcondyle point to the inferior point of the anterior Maxilla where ANS is 3mm thick

MnUL(mm) : Mandibular Unit Length the linear distance from the midcondyle point to pogonion.

MP-H(mm) : Mandibular Plane to Hyoid : The linear distance from H to the mandibular plane.

C3-H(mm) : Vertebral Hyoid : The linear distance between C_3 and H.

HRGN(mm) : Horizontal Hyoid : The linear distance between H and RGN.

VAL(mm) : Vertical Airway Length : The linear distance between PNS and Eb.

TNGXA(mm^2) : Tongue Cross-sectional area : The area outlined by the dorsal configuration of the tongue surface and lines which connect TT, RGN, H and Eb.

SPXA(mm^2) : Soft Palate Cross-sectional area : The area confined by the outline of the soft palate which starts and ends at PNS through P.

NASOXA(mm^2) : Nasopharynx Cross-sectional area : The area outlined by a line between R and PNS, an extension of the Palatal plane to the posterior pharyngeal wall, and the posterior pharyngeal wall.

OROXA(mm^2) : Oropharynx Cross-sectional area : The area outlined by the inferior border of the nasopharynx, posterior surface of the soft palate, a line from P to the dorsal surface of the tongue parallel to the palatal plane, the posterior inferior surface of the tongue, a line parallel to the palatal plane through the point Et, and the posterior pharyngeal wall.

HYPOXA(mm^2) : Hypopharynx Cross-sectional area : The area outlined by the inferior border of the oropharynx, the posterior surface of the epiglottis, a line parallel to the palatal plane through the point C4, and the posterior pharyngeal wall.

3) Tracings and digitization

All cephalometric radiographs were traced on an acetate paper by one investigator(JCK) and checked for accuracy by a second investigator(TO). Boundaries were outlined in the middle of the tissue transition

Table 2. Description of the obese groups

	Non-obese	obese	P
AGE	46.36(11.18)	43.58(11.39)	0.353
BMI	26.50 (2.20)	35.63 (4.33)	0.000***
AI	12.99(11.62)	23.79(25.27)	0.031*
RDI	32.03(15.63)	52.23(28.82)	0.001**

Mean(S. D.) *P<0.05 **P<0.01 ***P<0.001

Table 3. Oescription of small and large mandibular uint length groups

	small MnUL (N=29)	large MnUL (N=31)	P
AGE	45.41(10.70)	45.10(11.92)	0.914
BMI	29.01 (5.32)	31.23 (5.58)	0.121
AI	20.14(20.76)	14.77(16.97)	0.283
RDI	43.34(23.82)	37.52(24.20)	0.369

Table 4. Sample description according to OSA sererity

	mild(N=25)	moderate(N=17)	severe(N=18)	γ	p
AGE	45.56 (9.51)	45.77 (13.24)	44.33 (12.07)	-0.050	0.705
BMI	28.78 (4.64)	29.35 (4.58)	32.82 (6.69)	0.298	0.021*
AI	6.07 (4.17)	13.17 (6.33)	35.45 (24.40)	0.645	0.000***
RDI	20.39 (5.89)	37.53 (5.06)	68.14 (20.74)	0.847	0.000***

zones to account partial volume averaging. A data entry program was used by means of digitizer (Hewlett-Packard Model 9874 A). A cross hair cursor(Hewlett-Packard 1000 E series) was used to enter the contour of each structures into the computer.

4) Interpretation of data

To compare cephalometrics between upright and supine positions, t test was employed. The degree of obesity was assessed indirectly by employing body mass index(BMI=weight(kg)/height(m)^2), and the patients with BMI≥30 were classified as obese and those with BMI<30 as non-obese. A t test was used to compare airway size and cephalometric measurements between the groups. The obese group consisted of 24 patients and non-obese group consisted of 36 patients. The patients were divided into small(≤125mm) and large mandibular unit length groups (>125) and t test was performed to compare the anatomic structures between the groups. Small and large mandibular unit length groups consisted of 29 and 31 patients, respectively. The patients were also divided noto mild, moderate and severe groups according to OSA severity[47]. The patients with AI of 5~15 or RDI of 10~30 were grouped as mild group, with AI of 16~25 or RDI of 31~50 as moderate group and with AI of 25 or higher or RDI greater than 50 as severe group. Linear regression analysis using Pearson correlation coefficient was performed in mild, moderate and severe groups to compare their characteristics.

RESULTS

All patients were generally obese(BMI 30.16kg/m^2). Only 8 among 60(13.3%) patients were within normal value(accepted normal value is 19-25). Obese patients had significantly higher AI(23.79±25.27) and RDI (52.23±28.82) compared to the non-obese(AI 12.99±11.62, RDI 32.03±15.63)(Table 2). Mandibular unit length did not significantly affect AI or RDI(Table 3).

BMI was significantly differeent between mild(28.78±4.64), moderate(29.35±4.58) and severe(32.82±6.69) groups(Table 4). Obesity significantly influenced the severity of OSA.

ANB angle lower facial height, MP-H, vertical airway length, soft palate, oropharynx and hypopharynx cross-sectional areas differed between the two positions. From upright to supine, ANB angle increased from 4.56° to 5.37° and lower facial height increased from 75.19mm to 78.14mm. Vertical airway length shortened from 84.72 to 81.92mm. The cross-sectional area of soft palate significantly increased from 455.88 to 485.43mm^2. The cross-sectional area of orophorynx significantly decreased from 581. 56 to 500.16mm^2. The cross-sectional area of hypopharynx significantly increased from 253.67 to 287.77mm^2. In comparison between upright and supine positions, ANB angle and lower facial height significantly

Table 5. Comparison of upright and supine cephalmetrics in OSA patients(N=60)

	upright	supine	p
ANB	4.56 (2.59)	5.37 (2.27)	0.000***
LFH	75.19 (5.38)	78.14 (5.57)	0.000***
MxUL	98.05 (5.53)	98.10 (5.34)	0.858
MnUI	124.84 (6.13)	125.33 (6.56)	0.183
MP-H	26.39 (7.20)	24.43 (6.34)	0.029*
C3-H	43.61 (6.29)	44.30 (5.49)	0.275
H-RGN	42.59 (6.42)	41.27 (6.41)	0.062
VAL	84.77 (6.63)	81.92 (6.73)	0.000***
TNGXA	3790.96 (444.18)	3758.60(424.25)	0.327
SPXA	455.88 (112.02)	485.43 (114.13)	0.002**
NASOXA	266.78 (66.96)	268.99 (61.38)	0.481
OROXA	581.56 (177.71)	500.16 (148.11)	0.000***
HYPOXA	253.67 (122.80)	287.77 (142.50)	0.021*

*P<0.05 **P<0.01 ***P<0.001

increased in the supine position($p<0.001$). MP-H and vertical airway length shortened in the supine position. The cross-sectional areas of soft palate ($p<0.01$) and hypopharynx($p<0.05$) increased and that of oropharynx($p<0.001$) decreased in supine position. The cross-sectional area of tongue did not change by the postural change(Table 5).

Maxillary unit length, C3-H, cross-sectional area of soft palate significantly differed between obese and non-obese groups. In the upright position, the cross-sectional area of tongue and soft palate were 3609.29 and 417.36mm^2, respectively, in non-obese group and 4063.48 and 513.66mm^2 in obese group. In the supine position, corresponding areas were 3575.73

Table 6. Comparison of Non-obese(n=36) and obese(n=24) patients in upright and supine cephalometrics

	upright			supine		
	Non-obese	obese	p	Non-obese	obese	p
ANB	4.05 (2.24)	5.33 (2.92)	0.059	4.91 (1.97)	6.05 (2.55)	0.055
LFH	74.35 (5.33)	76.44 (5.33)	0.143	77.11 (5.39)	79.68 (5.61)	0.080
MxUL	96.54 (4.93)	100.33 (5.71)	0.008**	96.90 (4.88)	99.91 (5.60)	0.031*
MnUI	123.87 (5.40)	126.30 (6.96)	0.134	124.27 (6.27)	126.91 (6.78)	0.128
MP-HH	24.99 (6.38)	28.50 (7.95)	0.063	23.78 (6.23)	25.42 (6.50)	0.330
C3-H	41.98 (5.12)	46.05 (7.15)	0.013*	42.28 (5.33)	47.32 (4.28)	0.00***
H-RGN	41.47 (6.10)	44.27 (6.64)	0.098	40.13 (5.45)	42.98 (7.33)	0.092
VAL	83.26 (6.63)	87.05 (6.08)	0.029*	80.95 (6.47)	83.38 (6.98)	0.171
TNGXA	3609.29(384.14)	4063.48(390.39)	0.000***	3575.73(340.48)	4032.90(392.99)	0.000***
SPXA	417.36 (84.97)	513.66(124.08)	0.001**	449.79 (97.15)	538.88(118.67)	0.002**
NASOXA	270.91 (71.89)	260.58 (59.75)	0.563	274.98 (65.32)	260.01 (55.08)	0.359
OROXA	538.85(188.59)	645.62(140.04)	0.021*	474.41(163.90)	538.80(113.13)	0.099
HYPOXA	247.33(135.85)	263.18(102.19)	0.628	260.68(131.42)	328.41(151.43)	0.071

*P<0.05 **P<0.01 ***P<0.001

Table 7. Comparison of small(n=29) and large(n=31) mandibular unit length groups

	upright			supine		
	small Mn.U.L.	large Mn.U.L.	p	small Mn.U.L.	large Mn.U.L.	p
ANB	5.31 (2.68)	3.87(2.32)	0.029*	6.06 (2.57)	4.72(1.75)	0.020*
LFH	72.67 (4.75)	77.54(4.91)	0.000***	75.22 (4.70)	80.87(4.96)	0.000***
MxUL	95.02 (4.26)	100.89(5.11)	0.000***	95.63 (4.42)	100.42(5.14)	0.000***
MnUI	119.98 (3.93)	129.38(3.92)	0.000***	120.45 (4.20)	129.89(4.85)	0.000***
MP-HH	27.88 (7.25)	25.00(6.98)	0.122	24.60 (5.66)	24.27(7.01)	0.844
C3-H	42.63 (6.87)	44.52(5.65)	0.247	44.27 (4.41)	44.32(6.42)	0.972
H-RGN	42.38 (7.16)	42.79(5.74)	0.806	40.89 (5.88)	41.63(6.95)	0.658
VAL	84.38 (6.28)	85.14(7.03)	0.661	80.78 (6.07)	82.97(7.22)	0.206
TNGXA	3609.25(393.78)	3960.96(426.05)	0.002*	3605.78(414.08)	3901.57(387.62)	0.006**
SPXA	431.27(101.55)	478.90(117.99)	0.100	459.14(104.41)	510.02(118.94)	0.084
NASOXA	257.54 (56.45)	275.43(75.39)	0.305	262.86(57.29)	274.73(65.40)	0.459
OROXA	568.28(191.89)	593.98(165.56)	0.580	486.10(166.53)	513.32(129.95)	0.482
HYPOXA	233.73(117.99)	273.32(126.18)	0.227	290.40(138.28)	285.31(148.57)	0.891

*P<0.05 **P<0.01 ***P<0.001

Table 8. Cephalomeetrics in mild(=25), moderate(=17), severe(=18) groups in the upright cephalograms.

	mild	moderate	severe	γ	P
ANB	4.52 (2.88)	4.03 (2.13)	5.13 (2.57)	0.087	0.508
LFH	75.42 (5.25)	76.12 (4.45)	73.97 (6.37)	-0.104	0.431
MxUL	97.47 (4.56)	99.12 (6.66)	97.86 (5.78)	0.040	0.761
MnUI	125.50 (4.85)	126.26 (5.03)	122.58 (8.09)	-0.187	0.152
MP-HH	24.16 (6.47)	27.36 (7.70)	28.58 (7.18)	0.265	0.041*
C3-H	43.08 (5.38)	44.14 (6.14)	43.83 (7.74)	0.055	0.676
H-RGN	41.63 (5.86)	43.14 (7.60)	43.40 (6.14)	0.121	0.359
VAL	83.72 (6.27)	85.47 (6.69)	85.58 (7.23)	0.123	0.348
TNGXA	3674.69(416.13)	3880.71(479.85)	3863.70(435.19)	0.194	0.139
SPXA	432.50 (79.84)	448.74(143.87)	495.11(112.19)	0.231	0.076
NASOXA	282.42 (64.01)	271.96 (65.34)	240.16 (67.99)	-0.261	0.044*
OROXA	567.32(182.26)	644.68(156.72)	541.72(188.37)	-0.041	0.757
HYPOXA	257.36(141.91)	250.92(100.98)	251.13(119.48)	-0.023	0.864

*P<0.05 **P<0.01 ***P<0.001

Table 9. Cephalomeetrics in mild(=25), moderate(=17), severe(=18) groups in the supine cephalograms.

	mild	moderate	severe	γ	P
ANB	5.17 (2.74)	4.87 (1.47)	6.12 (2.07)	0.163	0.212
LFH	77.59 (4.72)	80.57 (5.78)	76.61 (6.02)	-0.050	0704
MxUL	97.64 (4.21)	99.00 (6.25)	97.90 (6.01)	0.030	0.822
MnUI	125.64 (6.07)	127.19 (4.81)	123.14 (8.18)	-0.176	0.178
MP-HH	22.72 (6.03)	25.16 (7.45)	26.12 (5.30)	0.231	0.076
C3-H	43.61 (5.90)	44.21 (5.41)	45.33 (5.12)	0.130	0.322
H-RGN	40.03 (6.04)	41.71 (5.60)	42.59 (7.58)	0.171	0.191
VAL	80.76 (5.75)	83.16 (8.57)	82.37 (6.12)	0.111	0.398
TNGXA	3763.57(378.76)	3794.57(475.73)	3841.34(436.13)	0.170	0.195
SPXA	458.48 (84.40)	494.34(136.64)	514.43(124.65)	0.210	0.107
NASOXA	285.88 (58.72)	274.65 (56.14)	240.20 (62.56)	-0.307	0.017*
OROXA	485.34(137.12)	531.79(127.28)	485.32(181.48)	0.000	0.997
	279.05(161.69)	296.75(124.03)	291.42(137.38)	0.048	0.719

*P<0.05 **P<0.01 ***P<0.001

and 449.79mm^2 in non-obese group and 4032.90 and 538.88mm^2 in obese group(Table 6).

ANB angle decreased(p<0.05) and lower facial height and maxillary unit length increased(p<0.01) in the large mandibular unit length group. The cross-sectional area of tongue was smaller in the small mandibular unit length group and larger in the large mandibular unit length group(p<0.01)(Table 7).

In comparison of mild, moderate and severe groups, cross-sectional area of nasopharynx was significantly decreased in upright and supine cephalograms with the increasing severity of OSA(p<0.05). Hyoid bone positioned inferiorly(mild 24.16mm, moderate 27.36 mm, severe 28.58mm in the upright position, mild 22.72mm, moderate 25.16mm, severe 26.12mm in the supine position) with the increaing severity of OSA. The cross-sectional area of tongue and soft palate increased with OSA severity, but did not have any statistical significance(Table 8, 9).

DISCUSSION

In the epidemiologic studies, the minimum prevalence of OSA among adults is about 1 percent[17,48,49]. 31 percent of males and 19 percent of female were habitual snorers and 60 percent of men and 40 percent of women between 60 and 65 years of age snored regularly. In this study, the mean age of the OSA patients was 45.25 years and it is similiar with other studies. Male : female ratio is reported to be between 10 : 1 and 60 : 1. In general, women with OSA weigh more than men with the syndrome[8]. In the current study, among the 63 OSA patients, only 3 patients were female. Male : female ratio in this study was 20 : 1.

Airway dimensions demonstrate cyclical variations with respiration[16,28,50]. Such dimensional changes largely depend on the intraluminal pressure changes resulting from constriction of the respiratory pump muscles and are affected by the magnitude of upper airway resistance. Because of this dynamic nature of the upper airway during respiration[51], cephalometric roentgenogram shoud be taken at exact time. In this study, we took x-rays at the end of expiration for homogeneous comparison.

Airway obstruction in OSA patients occurs in the supine position[52-54]. Postural changes of the body significantly affect lung physiology and muscular activity and, in turn, the airway size[55]. Fitzpatrick et al[56] have reported changes in upper airway dimensions with position. Previous studies reported that tongue volume increased and settled down in the supine position[54,57]. By this retrolapse of tongue, the cross-sectional area of oropharynx decreased 14.0% from upright to supine position. Pae[24] reported 36.6% reduction in cross-sectional area of oropharynx in OSA patients. Fouke and Strohlr[34] reported that pharyngeal volume in healthy subjects was 23% smaller in the supine than in the upright position with acoustic reflection technique. Pae[24] reported 20.1% reduction in the supine position in OSA group. In this study, only 4.1% reduction was found in the supine position. There were many studies that reported changing the sleeping posture is effective for OSA treatment[52,54,55].

A strong positive relationship between a thick neck and OSA was reported by many researches[58-60]. An increased mass loading of the upper airway may have contributed to the pathogenesis and severity of OSA. Horner et al[16] reported that there was significantly more fat around the pharynx in OSA patients. Kutz et al[60] found that there were fat deposits in soft palate and mentioned that the external neck circumference was larger in OSA group. In this study, the obese group had higher AI and RDI which is in agreement with other studies. In the obese group, the cross-sectional area of tongue and soft palate increased. It is probably due to the fat deposition in the tongue and soft palate. There were many reports that weight reduction is effective in some OSA patients[61,62].

Riley et al[46] found that 6 out of 10 OSA patients had mandibular deficiency. In the present study, however, no correlation was noted between mandibular unit length and OSA severity. This is not in agreement with other studies that OSA severity is related with mandibular length[9]. In the comparison of small and large mandibular unit length groups, lower facial height and maxillary unit length increased with the increase of mandibular unit length. The corss-sectional area of tongue increased significantly in large mandibular unit length group. These findings suggest that the large mandibular unit length group had larger capacity for the tongue. The cross-sectional area of tongue and soft palate slightly increased with the severity of OSA, but did not have any statistical significance. The cross-sectional area of the nasopharynx decreased significantly with the severity of the OSA in the present study. The hyoid bone in the OSA patient was more inferiorly located than the controls as described previously[18,24,40,64]. The position of the hyoid bone may be an important determinant of OSA because the muscles involving the tongue are attached to it and thereby influence the shape and the position of the tongue. If the hyoid bone is positioned inferiorly, the tongue moves backward and reduces the upper airway patency. Partinen et al[17] found that the higher RDI goup have large MP-H measurements. In the present study the hyoid bone also positioned more inferiorly as the severity increased. In other studies, there were reports that hyoid bone positioned inferiorly with increasing age[23] and OSA is prevalent in the middle age. The role of the position of the hyoid bone in OSA is further supported by the effect of surgery to advance the hyoid bone in the treatment of OSA[46,63]. In the current study, with the severity of the OSA, the hyoid bone positioned inferiorly. It is coincident with other studies that hyoid bone located inferiorly in OSA patients compare with normal subjects. The cross-sectional area of nasopharyx is decreased with the severity of OSA which is in agreement with Pae's result[24].

In the present study, we examined many aspects of craniofacial morphology and airway structures in OSA patients. Detection of predisposing structural abnormalities of the upper airway in such patients might be helpful in selecting an appropriate treatment.

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KOREA. J. ORTHOD. 1995 ; 25 : 655-664