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Adult craniocervical and pharyngeal changes—a longitudinal cephalometric study between 22 and 42 years of age. Part I: morphological craniocervical and hyoid bone changes

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SUMMARY The purpose of this study was to investigate longitudinally, by cephalometric means, alterations in craniocervical morphology and hyoid bone position in adult males and females, in three different age groups at 10-year intervals, and to compare the changes between the two genders. The material consisted of three series of cephalograms of 26 males and 24 females with approximately a 10-year interval between each series.

Alterations with increasing age in males and females included:

1 An increase in anterior and posterior facial height in both genders, a reduction in mandibular prognathism, and an increase in the mandibular plane angle in females only.
2 The hyoid bone assumed a more inferior position in relation to different skeletal structures for both sexes.
3 Head posture alterations were similar for the male and female group over time.

The overall significant inter-sex changes over a 20-year period were a reduction in mandibular prognathism, an increase in the mandibular plane angle in females, and a more inferior position of the hyoid bone in males.

Introduction

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 assess cranio-cervical angulation, pharyngeal relationships, soft palate dimensions, and hyoid bone and tongue position (Solow and Tallgren, 1976; Lowe *et al.*, 1985; Lyberg *et al.*, 1989; Haralabakis *et al.*, 1993; Ceylan and Oktay, 1995).

During the last two decades, considerable attention has been given to the position of the hyoid bone in relation to the facial skeleton during growth and function (Stepovich, 1965; Graber, 1978). Previous studies have shown that changes in mandibular position are related to hyoid bone changes and that hyoid bone position adapts to anteroposterior changes in head posture (Fromm and Lundberg, 1970; Opdebeeck *et al.*, 1978; Adamidis and Spyropoulos, 1983). Hyoid position has been studied in different adult groups and also longitudinally in denture wearers (Tallgren and Solow, 1984, 1987). They found that the hyoid bone was located more inferiorly in the two older age groups. Furthermore, Tourne (1991), in a review article, concluded that the hyoid bone descends considerably in older age groups to maintain function and compensate for the increase in bulk of the tongue. Except for these studies, little information is available concerning the longitudinal positional changes of the hyoid bone during adulthood.

The position of the hyoid bone may be an important consideration for obstructive sleep apnoea (OSA) because it anchors the musculature of the tongue (Maltais *et al.*, 1991). When this bone is low, the tongue is positioned further back, reducing airway patency. It has also been shown that, in OSA patients, the hyoid bone is located in a lower position, in relation to different skeletal structures, when compared with controls (Lyberg *et al.*, 1989; Shepard *et al.*, 1991; Tangugsorn *et al.*, 1995).

Cephalometric analysis is one of the more accepted techniques to evaluate upper airway and craniofacial morphology in OSA during the awake period (Andersson and Brattström, 1991). It is an inexpensive method for diagnostic purpose and treatment, and correlates with other more sophisticated and expensive techniques, such as computer tomography or somofluoroscopy (Haponik *et al.*, 1983; Suratt *et al.*, 1983). Many studies have shown that OSA patients have aberrated cephalometric variables, such as mandibular deficiency, elongated soft palate, enlarged tongue, decreased posterior airway space, inferior position of the hyoid bone, and altered craniocervical posture, when compared with a sample of normal individuals (Riley *et al.*, 1983; Guilleminault *et al.*, 1984; Bacon *et al.*, 1988; Solow *et al.*, 1993; Tangugsorn *et al.*, 1995).

It is also known that the prevalence of sleep disordered breathing events is increased in elderly adults (Carskadon and Dement, 1981; Coleman *et al.*, 1981; Smallwood *et al.*, 1983). The reasons for this increased prevalence are unclear. It is also unclear why there is a higher prevalence of sleep-induced respiratory disorders in men (Cisneros and Trieger, 1992). Possible explanations could be age-related reduction in the upper airway (UA) size, increased UA collapsibility, and/or inadequate compensatory action of the UA dilator muscles (Burger *et al.*, 1992). It is also possible that these alterations may appear later in life, but so far, little attention has been paid to such changes during adulthood.

The purpose of this study was to investigate, by cephalometric means, alterations in craniocervical morphology and hyoid bone position in adult males and females, in three different age groups with a 10-year interval.

Materials and methods

Lateral cephalometric radiographs were selected from the files of an adult growth study at the Department of Orthodontics, University of Oslo. This material consisted of cephalograms of all Norwegian dental students at the University of Oslo from 1972 to 1983 (Bondevik, 1995). From this material, 26 male and 24 female dental students were selected because of the availability of follow-up cephalograms after 20 years. The first cephalogram was taken during the third year of the dental curriculum of this group (T0) and two more were taken at 10-year intervals. At the first follow-up (T1), only 16 males and 13 females were available for a new cephalogram, but the entire male and female groups were present at the second follow-up (T2). The mean ages at the different recordings are shown in Table 1.

All individuals were in good health with no subjective sleep-induced breathing disorders.

Cephalometric analysis

All lateral cephalograms were taken using a Lumex B cephalostat (Siemens Norge A/S, Oslo,

Table 1 Mean ages for males and females at the different observations.

Recording	Males (n = 26)			Females (n = 24)		
	Mean	SD	Range	Mean	SD	Range
T0	22.29	1.78	21–28	22.69	1.95	21–28
T1	32.65	1.85	31–39	32.89	1.98	31–38
T2	42.72	1.88	41–49	42.91	1.96	41–49

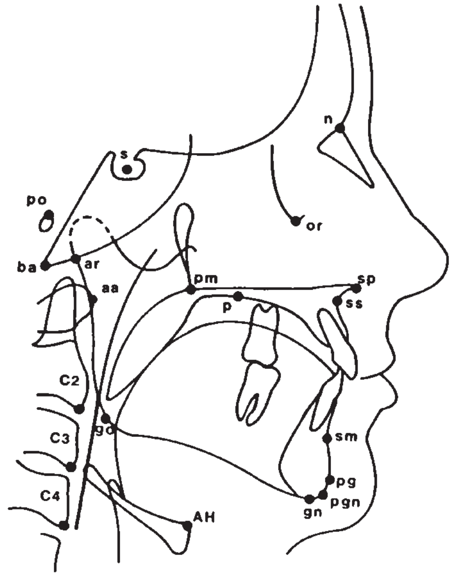

Figure 1 Cervicocraniofacial skeletal reference points used in this study: aa, anterior atlas; ar, articulare; ba, basion; C2–4, cervical vertebrae 2–4; gn, gnathion; go, gonion; n, nasion; or, orbitale; p, palate; pg, pogonion; pgn, prognathion; pm, pterygomaxillare; po, porion; s, sella; sm, supramentale; sp, spinale; ss, subspinale; AH, anterior hyoid (Lyberg *et al*., 1989, with the permission of the *Journal of Laryngology and Otology*).

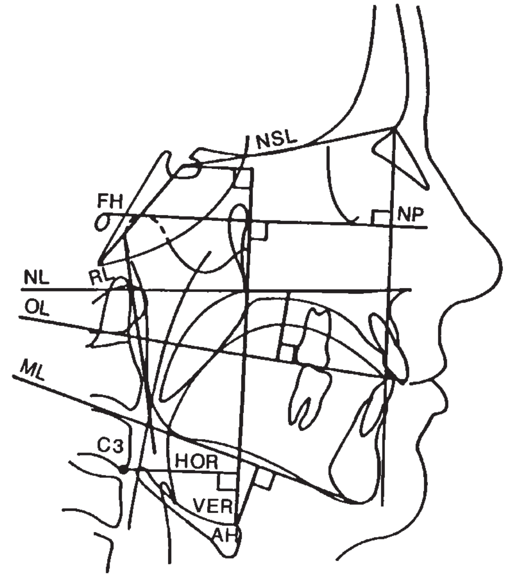

Figure 2 Reference lines used in this study: FH, Frankfort horizontal; ML, mandibular line; NL, nasal line; NP, nasion perpendicular; OL, occlusal line; NSL, nasion–sella line; RL, ramus line; AH–C3 Hor, horizontal position of hyoid bone related to the third cervical vertebra; AH–C3 Ver, vertical position of hyoid bone related to the third cervical vertebra (Lyberg *et al*., 1989, with the permission of the *Journal of Laryngology and Otology*).

Norway), with an intensifying screen and a motorized adjustable grid. The KVP (peak kilovoltage) was adjusted to optimize the contrast of both hard and soft tissues. The distance from the focus to the median plane was 180 cm and the median plane to film distance was 10 cm. Thus, the enlargement was 5.6 per cent, which was not corrected. The subject was seated with the median plane parallel to the film, with maximal intercuspation of the teeth, with the lips in light contact and in the natural head position (Moorrees and Kean, 1958). A possible lateral head tilt or rotation was prevented by means of a cross-light beam projected onto the face and, finally, the bilateral ear rods were gently inserted onto the external part of the auditory meatus to stabilize the head posture during exposure.

The reference points and lines used in this analysis are given in Figures 1–3. The definitions have been described in previous papers (Solow, 1966; Solow and Greve, 1979; Lyberg *et al*.,

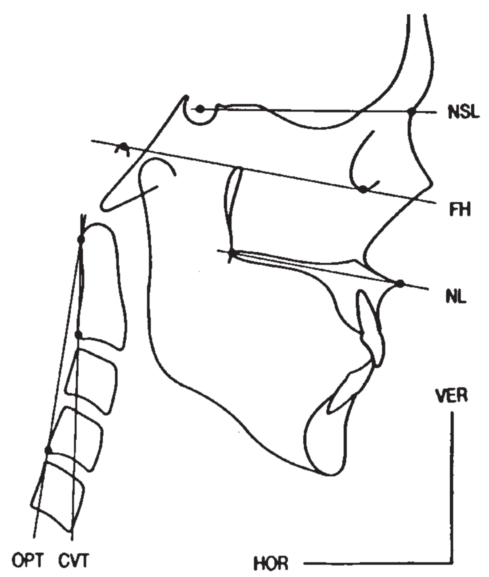

Figure 3 Reference points and lines used to study head posture: NSL, nasion–sella line; FH, Frankfort horizontal line; NL, nasal line; OPT, odontoid process tangent; CVT, cervical vertebra tangent; VER, true vertical; HOR, true horizontal (Solow and Greve, 1979).

1989). Some unfamiliar landmarks, plane, and measurements are described as follows.

1. Landmarks

aa	Anterior atlas, the most anterior point of atlas.
AH	Anterior hyoid, the most antero-superior point on the body of the hyoid bone.
C2–4	Cervical vertebrae 2, 3, and 4, the most antero-inferior point of the cervical vertebral bodies.
p	Palatale, the most cranial point of the palatal vault relative to the occlusal line(OL).

2. Linear measurements

AH–C3 Hor	The horizontal distance measured parallel to the Frankfort horizontal plane (FH) from the hyoid bone (AH) to the third cervical vertebra (C3).
AH–C3 Ver	The vertical distance measured perpendicular to the Frankfort horizontal plane (FH) from the hyoid bone (AH) to the third cervical vertebra (C3).
AH⊥FH	The vertical distance measured perpendicular to the Frankfort horizontal plane (FH) from the hyoid bone (AH) to the Frankfort horizontal plane (FH).
AH⊥ML	The perpendicular distance from the hyoid bone (AH) to mandibular line (ML).
AH–s Ver	The vertical distance measured perpendicular to the Frankfort horizontal plane (FH) from the hyoid bone (AH) to sella (s).
pm–ba	The length of the upper bony nasopharynx.
pm–aa	The length of the lower bony nasopharynx.

3. Angular measurements

NSL/VER	Head position in relation to the vertical.
NSL/OPT	Head position in relation to the cervical spine.
NSL/CVT	Head position in relation to the cervical vertebrae.
CVT/HOR	Inclination of the cervical column.
OPT/CVT	Cervical curvature (lordosis).

Reliability

All the lateral cephalograms were traced twice by hand on acetate tracing paper and digitized twice using the Dentofacial Planner computer program (Dentofacial Software Inc., Toronto, Canada) on an IBM 286/AT desktop computer. If the difference exceeded 1 mm or 1 degree, a third measurement was taken and the middle value of the two nearest measurements was used (Slagsvold, 1969).

Statistics

All the statistical procedures were performed using the Minitab computer program. The comparison of the means was obtained with the level of significance by using a two-tailed paired Student's *t*-test, except for the comparison between sexes, in which an unpaired Student's *t*-test was used.

Results

Craniofacial morphology

Angular measurements. The basal angular dimensions describing the facial skeletal morphology for the three different ages (T0, T1, and T2) are given in Table 2 for males and Table 4 for females. It is obvious that slight changes occurred during the period of the study for the male group (Table 3). For the females a significant posterior rotation of the mandible was found, which is expressed by the reduction of snsm from T0 to T1 and T2, and an increase in the angle ML/NSL during the observation time. Comparison of the means is summarized in Table 5.

Linear measurements. The increase in anterior (AFH) and posterior (PFH) lower facial height for the female group was found to be gradual. These changes were highly significant ($P < 0.001$) when T0 was compared with T2 (Tables 4 and 5).

Table 2 Males: cephalometric variables of facial morphology, hyoid bone position, and head posture for T0, T1, T2. Values are given in degrees and mm.

	Initial (T0) (n = 26)		1st follow-up (T1) (n = 16)		2nd follow-up (T2) (n = 26)	
	Mean	SD	Mean	SD	Mean	SD
Facial morphology						
nsba (°)	129.00	4.44	128.34	4.35	128.90	4.24
snss (°)	83.93	3.42	83.79	3.92	84.26	3.36
snsm (°)	81.30	3.22	80.47	3.21	81.01	3.26
NL/NSL (°)	8.03	2.83	7.90	2.12	7.68	2.73
ML/NSL (°)	27.53	4.95	26.61	5.05	27.7	4.71
FH/NSL (°)	7.30	2.54	7.44	1.66	7.7	2.54
AFH (mm)	125.12	6.29	124.34	5.79	126.32	6.15
PFH (mm)	85.38	3.76	86.28	4.28	87.3	4.61
Bony dimensions of pharynx						
pm–aa (mm)	36.21	3.91	35.79	3.07	35.29	3.56
pm–ba (mm)	47.43	4.02	47.03	3.75	46.65	3.76
Hyoid bone position						
AH–S Ver (mm)	113.20	6.62	114.99	6.14	118.75	6.74
AH⊥FH (mm)	93.11	5.36	93.91	5.04	97.50	6.12
AH⊥ML (mm)	14.87	5.24	15.58	5.47	16.06	4.78
AH–C3 Ver (mm)	6.4	7.5	7.80	7.53	13.05	5.99
AH–C3 Hor (mm)	39.07	5.20	39.60	4.46	40.22	4.19
Head posture						
NSL/VER (°)	96.29	4.87	96.45	4.01	97.28	3.94
NSL/OPT (°)	100.98	9.84	96.85	9.11	93.78	6.26
NSL/CVT (°)	107.39	9.12	102.08	8.84	98.81	5.57
CVT/HOR (°)	83.45	7.47	86.99	8.66	88.45	5.74
OPT/CVT (°)	6.32	2.54	5.20	2.35	4.96	2.96

In males, as well, both AFH and PFH were also found to increase significantly between T0 and T2 ($P < 0.01$ and $P < 0.001$, respectively; Tables 2 and 3). The bony elements of the nasopharynx (pm–aa, pm–ba) seemed to remain unchanged throughout this 20-year period for both males and females.

An additional finding was that hyoid bone was located more inferiorly in relation to different skeletal structures for both genders (Tables 2 and 4).

In males the descending of the hyoid was found to follow a gradual pattern, when this bone was related to the sella (AH–S Ver), the Frankfort horizontal (AH⊥FH) and the third cervical vertebra (AH–C3 Ver). The changes were found to be significant for all these cephalometric variables at the different age group comparisons, except for AH⊥FH between T0–T1. When this dimension was compared between T0 and T2, the difference was highly significant ($P < 0.001$). In relation to the mandibular plane (AH⊥ML) change in the vertical position of the hyoid was significant ($P < 0.05$) only between T0 and T2 (Tables 2 and 3).

In the female group vertical changes of the hyoid in relation to the sella (AH–S Ver) and the Frankfort horizontal (AH⊥FH) were found to be significant between T1–T2 ($P < 0.05$) and T0–T2 ($P < 0.01$). However, vertical differences of the hyoid bone in relation to the third cervical vertebra (AH–C3 Ver) and mandibular plane (AH⊥ML) were not significant (Tables 4 and 5).

Despite the vertical positional changes of the hyoid bone, its anteroposterior position (AH–C3 Hor) was found to be unchanged for both males

Table 3 Males: mean differences and *t*-values between T0, T1, and T2.

	T0–T1 (n = 26)		T1–T2 (n = 16)		T0–T2 (n = 26)	
	Diff. of means	*t*-value	Diff. of means	*t*-value	Diff. of means	*t*-value
Facial morphology						
nsba (°)	0.52	1.45	0.47	1.89	0.09	0.41
snss (°)	–0.22	–0.77	0.12	0.45	–0.32	–1.37
snsm (°)	–0.01	–0.08	–0.21	–0.71	0.29	1.52
NL/NSL (°)	0.22	0.80	-0.20	–0.55	0.32	1.29
ML/NSL (°)	0.47	1.20	–0.49	–1.46	–0.16	–0.75
FH/NSL (°)	0.04	0.09	0.26	0.51	–0.39	–1.42
AFH (mm)	–0.60	–1.44	0.32	0.78	–1.2	–3.68**
PFH (mm)	–1.42	–3.32**	–0.70	1.48	–1.9	–3.96***
Bony dimensions of pharynx						
pm–aa (mm)	0.79	1.43	0.56	1.23	0.92	1.68
pm–ba (mm)	0.58	1.20	0.45	1.15	0.78	1.54
Hyoid bone position						
AH–S Ver (mm)	–3.49	–3.75**	–2.95	–3.26**	–5.55	–5.49***
AH⊥FH (mm)	–2.11	–1.85	–2.81	–3.40**	–4.38	–3.78***
AH⊥ML (mm)	–0.57	–0.63	–0.47	–0.45	–1.19	–2.15*
AH–C3 Ver (mm)	–3.34	–2.03*	–4.27	–2.68*	–6.65	–4.71***
AH–C3 Hor (mm)	1.10	1.47	–0.70	–1.28	–1.15	–1.23
Head posture						
NSL/VER (°)	–0.64	–1.12	–0.92	1.28	0.99	1.23
NSL/OPT (°)	4.94	2.61*	2.62	1.30	6.74	3.73***
NSL/CVT (°)	6.27	2.88*	2.92	1.53	8.57	5.14***
CVT/HOR (°)	–4.48	–2.06*	–0.54	–0.27	–8.94	–5.19***
OPT/CVT (°)	0.70	1.36	0.26	0.40	1.36	3.43**

Level of significance: *P < 0.05; **P < 0.01; ***P < 0.001.

and females during the observation period (Tables 2 and 4).

Head posture. The four cephalometric variables determining the head posture in males and females are presented in Tables 2 and 4, respectively. The vertical head position (NSL/VER) was recorded to remain almost unchanged for both males and females. Head position was found to be closer to the cervical spine (NSL/OPT, NSL/CVT) with increasing age for both sexes. Cervical inclination (CVT/HOR) was significantly more upright at T1 and T2 for both genders. In addition, a decrease in cervical curvature (OPT/CVT) was found from T0 to T1 and T2, for males and females.

Inter-sex differences

Table 6 summarizes the statistically significant differences between males and females when comparing the changes between the initial observation (T0), and the second follow-up (T2). Differences significant at the 5 per cent level were found in snsm, ML/NSL, and AH⊥FH. The only significant differences at the 1 per cent level were measurements for the vertical hyoid bone position in relation to sella (AH–S Ver) and the third cervical vertebra (AH–C3 Ver).

Discussion

Numerous studies have described craniofacial growth in the first two decades of life, but less information is available on changes in craniofacial dimensions during adulthood (Krogman, 1973; Sarnäs and Solow, 1980). It is known, however, that dimensional changes do occur in the adult face in craniofacial and soft tissue morphology during the third and fourth decade of life (Forsberg, 1979; Behrents, 1985; Forsberg *et al.*, 1991).

Table 4 Females: cephalometric variables of facial morphology, hyoid bone position, and head posture for T0, T1, and T2. Values are given in degrees and mm.

	Initial (T0) (n = 24)		1st follow-up (T1) (n = 13)		2nd follow-up (T2) (n = 24)	
	Mean	SD	Mean	SD	Mean	SD
Facial morphology						
nsba (°)	129.64	3.89	128.12	3.45	129.17	4.09
snss (°)	83.22	3.11	83.51	2.77	83.07	3.04
snsm (°)	80.58	3.32	80.42	3.51	79.52	4.00
NL/NSL (°)	7.75	2.94	7.83	3.09	7.50	2.36
ML/NSL (°)	28.03	4.91	27.42	4.78	29.14	5.01
FH/NSL (°)	7.82	3.07	6.35	2.61	8.07	2.98
AFH (mm)	113.57	5.18	113.74	5.28	115.67	4.89
PFH (mm)	75.57	3.81	76.94	5.23	77.06	4.52
Bony dimensions of pharynx						
pm–aa (mm)	34.91	3.22	34.88	2.83	34.33	3.89
pm–ba (mm)	46.67	2.91	46.45	2.29	46.34	2.21
Hyoid bone position						
AH–S Ver (mm)	99.00	5.08	99.35	6.12	101.08	5.93
AH⊥FH (mm)	80.55	5.25	79.69	4.70	82.79	5.32
AH⊥ML (mm)	11.85	4.77	12.97	4.84	13.18	4.96
AH–C3 Ver (mm)	2.02	6.65	2.03	8.59	3.70	5.57
AH–C3 Hor (mm)	34.07	4.69	34.21	3.01	33.69	3.15
Head posture						
NSL/VER (°)	95.24	5.35	96.13	5.11	97.14	3.66
NSL/OPT (°)	97.26	9.57	92.55	9.35	91.62	7.12
NSL/CVT (°)	105.9	9.24	99.2	9.26	98.97	6.55
CVT/HOR (°)	83.99	7.17	89.24	6.15	92.16	5.89
OPT/CVT (°)	8.64	2.32	6.66	2.98	7.28	2.50

A total of 11 angular and 9 linear variables have been investigated for both genders in the present study. The overall changes in the craniofacial complex during the observation period were an increase in anterior (AFH) and posterior (PFH) facial height, in both sexes, and a reduction of mandibular prognathism (snsm) with an increase in mandibular plane angle (ML/NSL) in females only. These results are in agreement with the findings of Bondevik (1995), who investigated growth changes in an adult Norwegian sample from 23 to 33 years of age. The material of this study was selected from that used by Bondevik (1995), so it is logical that the same changes have been recorded. Some small differences can be attributed to the larger number used by Bondevik (males = 90, females = 74). Previous studies have also documented growth beyond the beginning of the third decade and indicated that facial changes are a continuous process during adulthood (Behrents, 1985).

A vertical elongation of the face is a common finding but the reason for this is not well understood. Ainamo and Talari (1976) suggested that elongation of the face during adulthood is the result of the continuous eruption of the teeth, together with an increase in alveolar height. This hypothesis is reinforced by other studies from Sarnäs and Solow (1980), and Forsberg *et al.* (1991).

In the present investigation the bony elements of the upper (pm–ba) and the lower (pm–aa) bony nasopharynx were shown to be almost unchanged for both genders. These results are in agreement with Biddy and Preston (1981), who found that the dimension pm–aa is determined in an early age. Also, Tourne (1991), in his review of the growth of the pharynx, concluded that

Table 5 Females: mean differences and *t*-values between T0, T1, and T2.

	T0–T1 ($n = 24$)		T1–T2 ($n = 13$)		T0–T2 ($n = 24$)	
	Diff. of means	*t*-value	Diff. of means	*t*-value	Diff. of means	*t*-value
Facial morphology						
nsba (°)	0.33	0.64	0.66	1.84	0.47	1.62
snss (°)	–0.16	–0.60	0.05	0.13	0.14	0.49
snsm (°)	0.68	2.05*	0.33	1.12	1.05	3.74**
NL/NSL (°)	0.32	1.93	0.13	0.39	0.25	0.74
ML/NSL (°)	–0.15	–0.40	–0.90	–2.05*	–1.10	–3.05**
FH/NSL (°)	0.19	0.60	–0.2	–0.95	–0.25	–0.98
AFH (mm)	–0.55	–1.22	–1.36	–3.16**	–2.1	–5.24***
PFH (mm)	–0.81	–1.62	–0.39	–1.14	–1.49	–4.20***
Bony dimensions of pharynx						
pm–aa (mm)	0.59	1.06	0.35	1.15	0.58	1.21
pm–ba (mm)	0.14	0.30	0.34	1.24	0.33	1.34
Hyoid bone position						
AH–S Ver (mm)	–0.525	–0.82	–2.28	–3.03*	–2.08	–3.51**
AH⊥FH (mm)	–0.4	–0.50	–2.59	–2.80*	–2.24	–3.06**
AH⊥ML (mm)	–1.03	–1.03	–0.8	–0.97	–1.33	–1.79
AH–C3 Ver (mm)	–1.17	–0.91	–0.94	–1.30	–1.67	–1.90
AH–C3 Hor (mm)	1.72	1.54	0.75	1.36	0.37	0.47
Head posture						
NSL/VER (°)	–0.24	–0.14	–1.6	0.99	1.90	1.24
NSL/OPT (°)	6.15	2.39*	2.45	1.09	5.64	3.76**
NSL/CVT (°)	8.06	3.16**	2.34	1.15	6.92	4.69***
CVT/HOR (°)	–7.06	–2.86*	–4.32	–2.85*	–7.41	–4.70***
OPT/CVT (°)	1.9	2.50*	0.00	0.01	1.36	3.33**

Level of significance: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 6 Statistically significant inter-sex differences. The means are in mm and degrees for linear and angular measurements, respectively.

	Mean females ($n = 24$) (T0–T2)	Mean males ($n = 26$) (T0–T2)	Mean difference	*T*-value
snsm (°)	1.05	0.29	0.75	2.27*
ML/NSL (°)	–1.10	–0.16	0.94	2.27*
AH–S Ver (mm)	–2.08	–5.55	3.46	3.06**
AH⊥FH (mm)	–2.24	–4.38	2.13	2.48*
AH–C3 Ver (mm)	–1.67	–6.65	4.97	3.11**

Level of significance: *$P < 0.05$; **$P < 0.01$.

the adult nasopharyngeal depth dimensions are established in early life and there is limited increase until adulthood.

The analysis of the cephalometric variables determining the position of the hyoid bone in relation to different skeletal structures shows that the mean vertical distances from hyoid (AH) to the sella (s), Frankfort horizontal (FH), mandibular line (ML), and third cervical vertebrae (C3) gradually increase with age for both genders. For males the changes for all these variables are significant when the initial

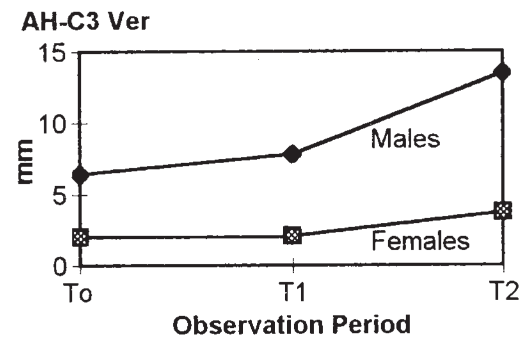

Figure 4 Vertical position of the hyoid bone in males and females (AH–C3 Ver).

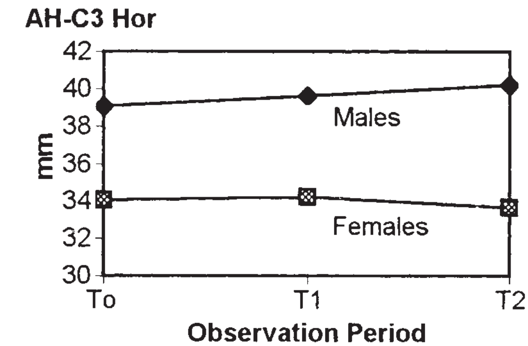

Figure 5 Horizontal position of the hyoid bone in males and females (AH–C3 Hor).

observation (T0) is compared with the second follow-up (T2), but for females only the two first variables were significantly different. From the comparison of the differences between the sexes it is clearly shown that hyoid bone assumes a more inferior position with age in males (Figure 4). Bench (1963) also described a descending of the hyoid bone in later ages, especially in males. Cohen and Vig (1976) stated that the tongue increases in bulk until maturity and becomes larger in relation to the intermaxillary space with increasing age, a trend that is more pronounced in males. Also our findings are in agreement with Maltais *et al.* (1991), who reported that the AH⊥ML distance was longer in the age-matched control subjects than in the younger control group, and the relationship between AH⊥ML and age was significant. Furthermore, Tallgren and Solow (1987), examining the hyoid bone position in three different age groups of adult Finnish women, found that the mean vertical distance of the hyoid bone to the upper face was significantly larger in the two older groups.

The horizontal position of the hyoid bone in relation to the third cervical vertebra was recorded to be stable, during the period of this study, for both genders (Figure 5). These results indicate that the horizontal distance of the hyoid is not influenced by age. This stable hyo-cervical relationship is probably due to the close anatomical and functional relationship of this bone to the laryngeal cartilage (Tallgren and Solow, 1987). Furthermore, it has been suggested that this stable hyoid position reflects the functional demand for maintenance of upper airway patency (Biddy and Preston, 1981; Haralabakis *et al.*, 1993).

The hyoid bone position is of great clinical interest because it plays an important role in maintaining the upper airway dimensions and an upright natural head posture (Brodie, 1950; Biddy and Preston, 1981). Thurow (1977) proposed that the geniohyoid muscle functions to adjust antero-posterior position of the hyoid bone and to maintain airway patency throughout the various movements of the craniofacial complex. A hyoid bone position on a level with the genial tubercle will increase the efficiency of this muscle in pulling the tongue forward. A more inferior position of the hyoid bone with a lower tongue posture places the geniohyoid muscle at a mechanical disadvantage by its angulation. This may increase the mandibular load because of the need to elevate the tongue, as well as causing a stronger opening force on the mandible (Thurow, 1977). These factors may aggravate an apnoea by facilitating the open mouth posture during sleep that is often observed in OSA patients (Hollowell and Suratt, 1991). A lower position of the hyoid bone was also found to be related to a higher OSA severity. When this bone is abnormally low, the tongue is positioned further back, thus reducing upper airway patency (Maltais *et al.*, 1991). It is also well documented in the literature that the prevalence of OSA increases with age and that there is also a gender predisposition (Smallwood *et al.*, 1983; Shepard *et al.*, 1991; Bresnitz *et al.*, 1994). Reasons for this increased occurrence in adult males are not well understood. The fact that the hyoid bone in this study was found to be in a more inferior position with age, and especially in the male group, may contribute to a better understanding of both the age and gender differences in the prevalence of OSA.

It is important for studies dealing with pharyngeal airway space and hyoid bone position to ensure an unstrained, reproducible position of the head, as well of the cervical column during exposure of the cephalometric radiograph (Davies and Stradling, 1990). Some authors have discussed the possibility that flexion or extension of the head influences pharyngeal airway space and hyoid bone position (Gustavsson *et al.*, 1972; Hellsing, 1989). In this study, the lateral cephalograms were taken in the natural head position according to Moorrees and Kean (1958). The results indicate that head posture changes over time in both genders.

Analysis of changes in head and cervical posture in the present sample revealed no significant mean changes in vertical head position (NSL/Ver) in both sexes. However, the angle between the cervical column and the horizontal (CVT/HOR) increased, the cervical column displayed decreased lordosis (OPT/CVT), and the craniocervical angulation (NSL/CVT) became smaller. These changes, which were similar for both males and females, would tend to bring the posterior pharyngeal wall closer to the tongue. However, the horizontal position of the hyoid bone (AH–C3Hor) did not alter significantly, probably reflecting the demand for maintenance of hypopharyngeal airway patency.

Tallgren and Solow (1987) examined head posture changes in three different age groups of adult Finnish women. They found that head position in relation to the vertical was more upwards in the two older groups, but the remainder of the postural changes were not significant. Differences between our study and the latter could be attributed to the different age groups, as well as the fact that the other investigation was cross-sectional.

Conclusions

1. Craniofacial growth continues beyond the third decade of life. Overall, changes with age are an increase in anterior and posterior facial height in both genders, a reduction in mandibular prognathism, and an increase in mandibular plane angle in females only.
2. The hyoid bone assumes a more inferior position in adult life in relation to various skeletal structures for both men and women. In males, the descent of the hyoid bone is significantly more pronounced than in females. However, the horizontal position of the hyoid bone was found to be stable.
3. Head posture changes over time, but variations are similar for both genders.

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