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Cephalometric changes in adult pharyngeal morphology

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SUMMARY This cephalometric study investigated morphological changes occurring in the pharynx between early and middle adult life. A sample of 16 young adults (mean age 20.2 years) had cephalometric films taken and repeated after an interval of 32 years. Changes in pharyngeal skeletal size, pharyngeal soft tissue thickness, pharyngeal airway depth, and soft palate dimensions were examined, in addition to standard craniofacial measurements. The results showed increases in maxillary prominence, and upper and lower anterior face height. The nasopharyngeal skeletal dimensions were unchanged over the 32-year interval, while the anteroposterior depth of the nasopharyngeal lumen increased as a result of a reduction in thickness of the posterior nasopharyngeal wall. In the oropharynx, the depth of the airway decreased with age, and the soft palate became longer and thicker.

The findings indicate that pharyngeal morphology is not immutably established during childhood and adolescence, but changes throughout adult life. The tendency towards a longer and thicker soft palate, and narrower oropharynx during adulthood is discussed in relation to their possible role in explaining the increased prevalence of obstructive sleep apnoea and related disorders in later life.

Introduction

The form and function of the pharynx has been of interest to orthodontic researchers for many years. While the typical growth pattern of the pharynx in children and adolescents has been elucidated using growth study material (Linder-Aronson and Leighton, 1983; Taylor *et al*., 1996), little attention has been paid to the changes which occur during later life.

The recognition of sleep disordered breathing as a common clinical problem, particularly obstructive sleep apnoea (OSA) which affects 2–4 per cent of middle aged men (Young *et al*., 1993), has intensified interest in normal and abnormal pharyngeal morphology. The current consensus on the aetiology of OSA is that it results from a variable combination of pharyngeal anatomical and pathophysiological factors (Battagel, 1996), although the relationship between these factors is still poorly understood and remains an area of investigation (Pracharktam *et al*., 1996). Radiographic cephalometry has proved useful for investigating the aetiology of OSA, as several studies have shown that OSA patients have reduced anteroposterior pharyngeal dimensions, larger soft palates, and a retrognathic skeletal pattern (Lowe *et al*., 1986; Bacon *et al*., 1990; Ono *et al*., 1996; Pracharktam *et al*., 1996; Solow *et al*., 1996; Pae *et al*., 1997). Other cephalometric studies have, however, failed to show significant cephalometric differences between OSA patients and controls (Mayer and Meier-Ewert, 1995).

While OSA has been reported in adolescents and children (Guilleminault *et al*., 1976), it is most common in middle aged adults, although the reasons for the greater incidence of the disorder in later life have not been fully elucidated (Douglas, 1995). Obesity is known to be a factor (Douglas, 1995; Lowe *et al*., 1995) and there is also evidence that there is a familial background to OSA in some patients (Mathur and Douglas, 1995). Subtle changes in airway morphology may also be important, although there has been no published report of longitudinal data which would help to support or refute this hypothesis. Before any abnormal pharyngeal changes leading to OSA can be identified, a better understanding is required of

Table 1 Definitions of cephalometric points, planes and measurements.

Points	
A	Point A
AA	Most anterior point on the atlas vertebra
ans	Anterior nasal spine
Ar	Articulare
B	Point B
Ba	Basion
Go	Gonion
Me	Menton
N	Nasion
pns	Posterior nasal spine
Ptm	Pterygomaxillare
S	Sella
So	Constructed point at the midpoint of distance sella–basion
TD	Tongue dorsum, intersection of perpendicular from the midpoint of Ev–TT and the dorsum of the tongue
TT	Tip of the tongue or the lower incisor cingulum, where the tip of tongue was not visible
U	Tip of the uvula
V	Vallecula
Constructed points and lines	
ML	Mandibular line (menton to lower border of mandible at the angle)
NL	Nasal floor line (ans to pns)
RL	Ramus line (Ar to posterior border of mandible at the angle)
TAFH	Total anterior face height, N–Me
UAFH	Upper anterior face height, N–ans
LAFH	Lower anterior face height, ans–Me
Ad1	Intersection of the line ptm–basion and the posterior pharyngeal wall
Ad2	Intersection of the line ptm–So and the posterior pharyngeal wall
apw1	Intersection of NL and the anterior pharyngeal wall
apw2	Intersection of the line parallel to NL, through the midpoint of the line pns–U, with the posterior surface of the soft palate.
apw4	Intersection of the line B–Go with the anterior pharyngeal wall
ppw1	Intersection of NL and the posterior pharyngeal wall
ppw2	Intersection of the line through the midpoint of pns–U, parallel to NL, with the posterior pharyngeal wall
ppw3	Intersection of the line through U, parallel to B–Go, with the posterior pharyngeal wall
ppw4	Intersection of the line B–Go with the posterior pharyngeal wall
TongL	Estimated tongue length = distance V to the cingulum of the lower incisor
TongHt	Tongue height = distance from the midpoint of the line V–TT to TD
SPalLg	Soft palate length = distance pns–U
SPalTh	Soft palate thickness measured along the line through the midpoint of pns–U parallel to NL

the normal changes in the pharynx which occur during adult life.

The current study investigated the morphological changes in the nasopharynx (the region of the pharynx above the level of the hard palate) and the oropharynx (below the hard palate) between early adulthood and middle age in a group of healthy adults.

Subjects and methods

The cephalometric material had been collected as part of an earlier study, which had investigated dentofacial changes during adulthood. Sixteen young adults (11 males and five females) had cephalometric films taken at a mean age 20.2 (SD = 2.6) years (T1) with a second film recorded for each subject at a mean age 52.4 (SD = 2.7) years (T2). The subjects were orientated with the Frankfort plane horizontal, the maxillary and mandibular teeth in centric occlusion, and with the oropharyngeal musculature relaxed. No contrast medium was used, as the pharyngeal tissues were clearly visible on the films.

Each film was traced and a total of 30 measurements (defined in Table 1 and Figure 1) were

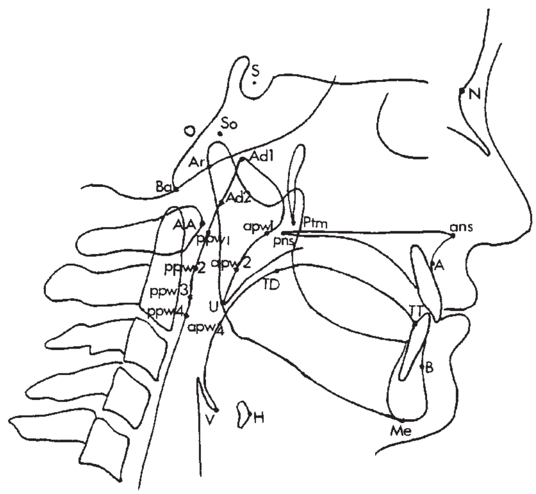

Figure 1 Cephalometric points and lines used in the study.

recorded using a SSi/Microcad Lightmaster backlit digitizing system 1624LM-PC (SSi Microcad, Pewsey, Wiltshire, UK) and a GTCO T5 16-button Clearvu Cursor (GTCO Corporation, Columbia, Maryland, USA) connected to a Nimbus VX/2 personal computer (Research Machines Ltd, Oxford, UK). All linear measurements were corrected for magnification to facilitate comparison with other published data.

The error of the method was assessed using replicate tracings and measurements on all the films with the method error values calculated using the formula described by Dahlberg (1940). In addition, paired *t*-tests were used to detect any systematic differences between the original and replicate measurements (Houston, 1983).

For each measurement, the mean T1 and T2 values were compared using paired *t*-tests.

Results

The mean values for each variable at 20 (T1) and 52 (T2) years of age, and the mean changes occurring during the intervening period are shown in Tables 2 and 3. The method error varied between 0.35 and 1.56 mm for linear measurements, and between 0.39 and 1.58 degrees for angular measurements. No differences between the original and replicated measurements were detected at the 10 per cent level of significance.

Skeletal changes (Table 2)

The angles SNA and ANB increased during adulthood ($P < 0.01$), although there was no significant change in SNB. Measurement of anterior facial dimensions showed significant increases in upper anterior face height (UAFH), lower anterior face height (LAFH), and total anterior face height (TAFH). No significant

Table 2 Means, standard deviations, and differences (between T1 and T2) for skeletal measurements.

Skeletal	T1 Mean ± SD	T2 Mean ± SD	Difference between means (T2 – T1) Mean ± SE
SNA (°)	80.34 ± 4.07	81.53 ± 4.10	1.19 ± 0.24**
SNB (°)	78.56 ± 3.74	78.50 ± 3.92	–0.06 ± 0.39 NS
ANB (°)	1.81 ± 2.26	3.03 ± 2.50	1.22 ± 0.33**
S–N (mm)	67.00 ± 3.14	68.66 ± 3.32	1.65 ± 0.59**
Ba–S–N (°)	126.81 ± 5.20	125.47 ± 7.23	–1.34 ± 0.66 NS
Ptm–A (mm)	46.96 ± 2.99	49.22 ± 3.45	2.26 ± 0.35**
Ptm–S (mm)	44.28 ± 3.87	44.99 ± 3.92	0.70 ± 0.37*
SN:NL (°)	6.34 ± 2.79	5.47 ± 3.10	–0.88 ± 0.38*
ML:NL (°)	25.13 ± 4.70	25.69 ± 5.21	0.56 ± 0.36 NS
RL:ML (°)	118.84 ± 6.86	118.78 ± 7.22	–0.06 ± 0.42 NS
UAFH (mm)	51.60 ± 3.50	52.44 ± 3.57	0.86 ± 0.39*
LAFH (mm)	64.75 ± 5.47	66.81 ± 5.80	2.05 ± 0.34**
TAFH (mm)	116.35 ± 8.38	119.28 ± 8.10	2.92 ± 0.36**
LAFH/TAFH	0.56 ± 0.02	0.56 ± 0.02	0.01 ± 0.00 NS

NS, not significant; $*P < 0.05$; $**P < 0.01$.

Table 3 Means, standard deviations, and differences (between T1 and T2) for pharyngeal measurements.

	T1 Mean ± SD	T2 Mean ± SD	Difference between means (T2 – T1) Mean ± SE
AA–Ptm (mm)	31.24 ± 2.55	31.28 ± 2.25	0.04 ± 0.57 NS
Ba–Ptm (mm)	40.22 ± 2.32	40.23 ± 2.22	0.01 ± 0.32 NS
So–Ptm (mm)	35.99 ± 2.44	36.09 ± 2.03	0.10 ± 0.37 NS
Ad1–Ba (mm)	17.59 ± 2.87	16.25 ± 2.41	–1.26 ± 0.50*
Ad2–So (mm)	17.56 ± 3.35	14.49 ± 3.09	–3.07 ± 0.60**
Ad1–Ptm (mm)	22.66 ± 2.54	23.93 ± 2.50	1.26 ± 0.52*
Ad2–Ptm (mm)	18.49 ± 2.88	21.60 ± 2.68	3.11 ± 0.65**
apw1–ppw1 (mm)	17.51 ± 2.18	17.01 ± 3.84	–0.50 ± 0.70 NS
apw2–ppw2 (mm)	11.58 ± 1.96	9.07 ± 2.58	–2.50 ± 0.61**
U–ppw3 (mm)	10.71 ± 2.66	8.73 ± 1.81	–1.98 ± 0.61**
apw4–ppw4 (mm)	11.46 ± 3.90	9.96 ± 2.26	–1.49 ± 1.18 NS
Ptm–V (mm)	67.67 ± 5.70	72.37 ± 5.65	4.70 ± 0.60**
TongL (mm)	70.34 ± 4.41	74.07 ± 6.16	3.72 ± 1.22**
TongHt (mm)	36.23 ± 3.78	37.78 ± 4.00	1.55 ± 1.06 NS
SPalLg (mm)	31.36 ± 3.63	35.55 ± 4.61	4.19 ± 0.84**
SPalTh (mm)	9.10 ± 1.45	10.70 ± 2.67	1.60 ± 0.61*

NS, not significant; *$P < 0.05$; **$P < 0.01$.

changes in the mandibular to maxillary planes angle (ML:NL), the gonial angle (RL:ML), or the ratio of lower anterior face height to total anterior face height were observed, although the angle between the cranial base and the maxillary plane (SN:NL) decreased ($P < 0.05$).

The anterior cranial base length (S–N) increased significantly ($P < 0.01$), while the cranial base angulation (Ba–S–N) was not significantly different at T2 compared with T1. The mean maxillary length (Ptm–A) increased by 2.26 mm ($P < 0.01$).

Pharyngeal measurements (Table 3)

The skeletal dimensions of the nasopharynx (as represented by the distances AA–Ptm, Ba–Ptm, and AA–Ptm) remained stable, showing no significant changes between T1 and T2. The thickness of soft tissue in the posterior nasopharyngeal wall decreased at Ad1–Ba ($P < 0.05$) and Ad2–So ($P < 0.01$), while the sagittal depth of the pharyngeal lumen in this region increased when measured as Ad1–Ptm ($P < 0.05$) and Ad2–Ptm ($P < 0.01$). In contrast, the sagittal depth of the oropharyngeal lumen (apw2–ppw2 and U–ppw3) reduced ($P < 0.01$). The vertical pharyngeal length (Ptm–V) increased by a mean of 4.70 mm ($P < 0.01$).

Soft palate and tongue (Table 3)

There were increases in the soft palate length SPalLg ($P < 0.01$) and thickness SPalTh ($P < 0.05$). The tongue length (TongL) became greater with age ($P < 0.05$), although there was no significant change in tongue height (TongHt).

Discussion

The number of subjects available for inclusion in the investigation was small and, therefore, the present work should be regarded as a pilot study. Due to the limited number of subjects, the male and female results were pooled, and it is possible that there may have been a sex difference in the findings. Some of the skeletal changes observed in the current study were larger than those reported by Bondevik (1995), who examined craniofacial changes in Norwegian adults. These differences in findings may be due to the longer time interval between T1 and T2 in the current study (32 years) compared with the 11-year interval in Bondevik's material. A further factor may be that, while the initial cephalometric films were recorded at 22 years of age in Bondevik's study, those in the current investigation were taken at 20 years of age, when there may have been relatively more late adolescent growth remaining in some of the subjects. Genetic differences and the smaller sample size of the current data may also be important.

Despite the increase in maxillary prominence (SNA) and maxillary length (Ptm–A), no changes in the distances between the pterygomaxillary fissure (Ptm) and the posterior bony limits of the pharyngeal space (the atlas and the middle cranial base) were observed. Tourne (1991) reviewed the growth of the pharynx and concluded that the adult bony nasopharyngeal depth was established early in life, although other studies have shown increases up to 12 (Taylor *et al*., 1996) and 16 years of age (Linder-Aronson and Leighton, 1983). Our results indicate that the sagittal depth of the bony nasopharynx does not undergo any significant change after 20 years of age.

With regard to the soft tissue borders of the nasopharynx, the results showed a reduction in thickness of soft tissue in the posterior pharyngeal wall during adulthood. This was evident in the region of the posterior nasopharyngeal wall, which is occupied by adenoidal lymphoid tissue in the child and adolescent. Linder-Aronson and Leighton (1983) reported a continuing reduction in posterior pharyngeal wall thickness and an increase in the sagittal depth of the nasopharyngeal airway between the ages of 5 and 16. It is apparent from the present results that this trend continues throughout adult life. In contrast, however, in the oropharynx (the area of the pharynx below the level of the hard palate), the airway depth behind the soft palate (apw2–ppw2 and U–ppw3) became smaller after 20 years of age. The airway depth at apw4–ppw4 remained unchanged, and this may reflect adaptive changes in head posture or tongue position to maintain airway patency.

The results show that vertical pharyngeal length increased by 4.70 mm after 20 years of age. This was also reflected in the significant increase in lower face height, agreeing with the findings of Pae *et al*. (1997), who recently demonstrated an association between lower anterior face height and vertical pharyngeal length. Tourne (1991) claimed that the vertical growth of the nasopharynx paralleled sexually-determined skeletal growth and continued until skeletal maturity (at approximately 13 years of age in girls and 18 years of age in boys according to Tourne). The current findings indicate that vertical growth in pharyngeal length actually continues during later life.

OSA has been shown to be associated with a small bony pharyngeal skeleton and a small oropharyngeal airway (Lowe *et al*., 1986; Bacon *et al*., 1990; Tangugsorn *et al*, 1995a; Ono *et al*., 1996; Pracharktam *et al*., 1996; Pae *et al*., 1997). The present results indicate that, although the bony pharyngeal dimensions are unchanged during adulthood in normal subjects, there is a reduction in the oropharyngeal airway depth behind the soft palate between early and late adulthood. If changes in pharyngeal morphology during life are, indeed, a factor in explaining the increasing prevalence of OSA with age, then it seems likely that soft tissue, rather than skeletal changes are responsible. It is therefore possible that small bony pharyngeal dimensions established early in life may predispose to OSA development later, when subsequent soft tissue changes further reduce the available oropharyngeal airway to the extent that the features of OSA become apparent.

The soft palate has been previously shown to be longer in patients with OSA than in controls (Bacon *et al*., 1990; Tangugsorn *et al*., 1995b). The current observation of an increase in soft palate length during adulthood in normal subjects is therefore interesting, particularly when considered together with the reported increase in OSA incidence with age (Douglas, 1995). While lengthening of the soft palate appears to be a normal feature of ageing, it may also be an important factor in individuals otherwise predisposed to OSA.

Conclusions

The longitudinal data in the present study indicate that, while the bony periphery of the nasopharynx remains stable during adulthood, soft tissue changes are responsible for an increase in the sagittal depth of the nasopharynx, but a reduction in the sagittal depth of the oropharynx posterior to the soft palate. In addition, the soft palate length and thickness, and the vertical pharyngeal length increase with age. Similar changes may be important, particularly in patients with small bony pharyngeal dimensions, in explaining the increased incidence of OSA and related disorders, which has been reported to occur during later life.

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