SCIENTIFIC SECTION

Non-apneic snoring and the orthodontist: radiographic pharyngeal dimension changes with supine posture and mandibular protrusion

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Objective: To evaluate the radiographic changes that occur in the pharynx and surrounding structures with alteration of posture from the upright to the supine position and the effect that mandibular protrusion whilst supine has on these dimensions.

Design: Prospective cephalometric study.

Setting: University Dental Hospital and School.

Subjects and method: This prospective study involved 35 consecutively referred adults with proven non-apneic snoring. Lateral skull radiographs were obtained with the subjects upright in occlusion, supine in occlusion and supine with the mandible protruded to the maximum comfortable position. Radiographs were traced and digitized, and the pharyngeal dimensional changes and hyoid position were examined. Males and females were examined separately.

Results: Radiographic pharyngeal dimensions were changed with altered posture, resulting in significant reductions in the minimum post-palatal ($p < 0.01$) and post-lingual ($p < 0.05$) airway measurements in the supine position. Mandibular protrusion whilst in the supine position produced increases in the functioning space for the tongue.

Conclusion: A supine posture results in significant reductions in pharyngeal airway measurements of non-apneic snorers. Mandibular protrusion whilst in the supine position produces an increase in the functioning space for the tongue.

Key words: Non-apneic snoring, pharyngeal dimensions, protrusion, supine

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Introduction

The prevalence of snoring in the UK adult population is estimated at 40%.[1] Non-apneic snoring is thought to be due to a combination of anatomical and patho-physiological factors. For example, abnormal airway compliance[2] superimposed on unfavorable pharyngeal anatomy[3] predisposes to airway narrowing and thus snoring. Furthermore, a supine sleeping posture is thought to further reduce the airway due to the effect of gravity on the soft tissues.

Investigations into snoring have focused on the anatomy and pathophysiology of the airway in the upright and the supine positions. Studies using radiography, fluoroscopy, magnetic resonance imaging and computer tomography have been undertaken to assess differences between patients with sleep-related breathing disorders and controls. These have shown craniofacial and pharyngeal morphological differences in those with sleep-related breathing disorders[4–9] with apneic and non-apneic snorers showing similar, but not identical skeletal and pharyngeal characteristics.[3,8,10,11] Cross-sectional data from computer tomography and magnetic resonance imaging suggest that the shape of the pharynx differs in subjects with sleep-related breathing disorders, with these subjects having the widest section of their elliptical pharynx in the sagittal view,[8] and increases in the size and shape of the soft tissues of the soft palate,[12] tongue,[5] lateral pharyngeal walls.[9] Cephalometry has shown a shorter anterior cranial base, a reduced cranial base angle, bimaxillary retrognathia, an increased

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maxillary mandibular planes angle and lower facial height, an inferiorly positioned hyoid and an increase in craniocervical angle in subjects with OSA.[4–7,13]

Lateral cephalometry is a readily available, inexpensive and reliable technique for assessing the pharyngeal airways, whereby details of skeletal and soft tissue structures can be accurately measured and compared with extensive normative data. However, it is a two-dimensional static representation of a dynamic three-dimensional structure and changes in the transverse dimension are difficult to determine. Airway dimensions alter in function and with level of consciousness of the subject, and therefore radiographs taken in awake subjects do not give a true representation of the situation in sleep-related breathing disorders. They do, however, allow comparison of craniofacial and pharyngeal dimensions with normal individuals.

A supine posture is thought to better simulate the sleeping position and allow the effect of gravity on the soft tissues to be visualized.[14] Studies, using various imaging techniques, have found that pharyngeal airway dimensions reduce with a supine posture in subjects with OSA.[11,14,15] These dimensions have been shown to improve with mandibular protrusion whilst supine.[16–19] Few studies have examined the effect of posture on non-apneic snorers and none has reported the effects of mandibular protrusion in this group. Data are confined to OSA subjects.

The aims of this study, therefore, were to determine the effect of altered posture and mandibular protrusion on the radiographic pharyngeal airway of non-apneic snorers.

Subjects

The study utilized three lateral radiographs of 35 dentate, Caucasian adults (20 males, 15 females) with non-apneic snoring. All subjects had been consecutively referred to the department of orthodontics from the Royal National Throat Nose and Ear Hospital, London, for the construction of a custom made removable, adjustable Herbst mandibular advancement splint. A definitive diagnosis had been made in a multidisciplinary setting following overnight polysomnography and the treatment of choice for these subjects was a MAS rather than palatal surgery.

Demographic data of height and weight were recorded, and the body mass index (BMI) calculated. All subjects received a comprehensive patient information leaflet prior to entry into the study and written consent was gained from all individuals. Ethical approval was attained from ELCHA research ethics committee.

Method

Radiography

All subjects had a standardized lateral cephalogram taken as part of the normal protocol for the management of subjects with sleep-related breathing disorders with a mandibular advancement splint (MAS). A thin layer of barium sulfate contrast medium was applied to the dorsum of the tongue to enhance soft tissue landmark identification. The subjects were asked to hold their natural head position whilst seated in the cephalostat and to occlude on their posterior teeth. To standardize hyoid position, the radiographs were exposed at the end of expiration and the patients were asked to practice this position before the films were taken. The radiographs were taken using a standardized technique and magnification factor by radiographers familiar with the study protocol.

Two supine lateral skull radiographs were also taken prior to fitting the appliance. These films were obtained using an adjustable Orbix machine (Siemens PLC, Bracknell, Berkshire, UK). The first supine film was taken with the subjects occluding on their posterior teeth and the second with the mandible held in a position of maximum comfortable protrusion. This protrusion was measured and maintained with a constructed wax wafer. A standardized protocol was used when taking the supine radiographs. However, head position could not be as carefully controlled as when using a cephalostat. Patients were asked to adopt a supine sleeping posture, the lateral head position was then aligned by the radiographer and the head held with a foam support. Contrast medium was applied to the tongue and the radiographs were exposed at the end of expiration by radiographers familiar with the radiographic protocol. Again, the patients were asked to practise this position before the films were taken. On reviewing the radiographs, film definition and left/right superimposition was not as good as seen on a cephalogram. Despite a standardized protocol and a validated technique[15] being used for taking the supine films, unfortunately several were of insufficient quality to be included in the study, thereby reducing the sample sizes in the groups: males $n = 18$, females $n = 14$.

Cephalometric analysis

The radiographs were traced by one examiner (AMS) under standardized lighting conditions in a darkened room and then orientated at 7° to the S–N line. Twelve conventional cephalometric landmarks (Figure 1) and 19 additional points relating to the oropharynx were recorded (Figure 2). These points were digitized twice to a tolerance of 0.2 mm and the mean value taken. The outlines of the soft palate, tongue and oropharynx were

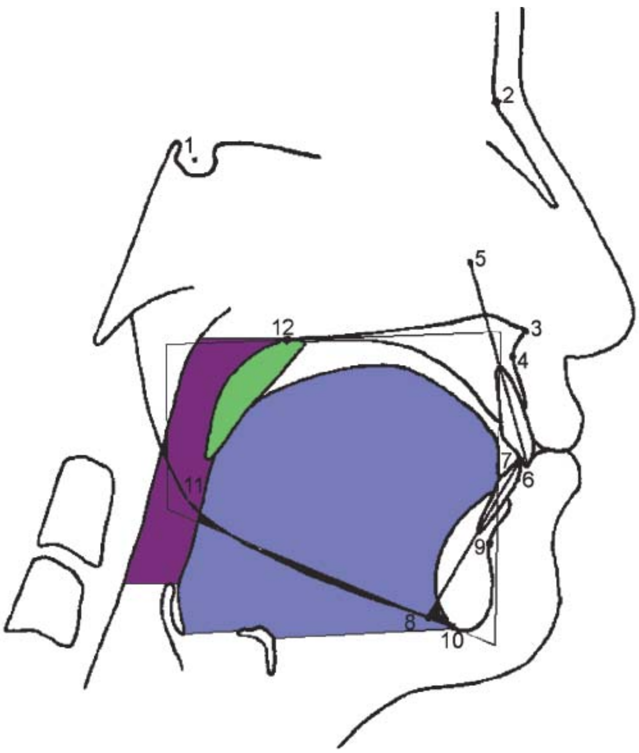

Figure 1 Standard cephalometric landmarks and pharyngeal area measurements recorded. Except where listed below, points, lines and planes conform to British Standard definitions.[31] *Points:* 1, sella; 2, nasion; 3, ANS; 4, point A; 5, upper incisor apex projection to Frankfort Horizontal; 6, upper incisor tip; 7, lower incisor tip; 8, lower incisor apex projection to the mandibular plane; 9, point B; 10, menton, (point of intersection of lower mandibular border and symphyseal outline); 11, gonion; 12, PNS. Area measurements are displayed in color; tongue area in blue, oro-pharyngeal area in purple, and soft palate area in green. Intermaxillary space is outlined in black. *Tongue area:* delineated by the outline of the tongue within the oral cavity extending down to vallecula, across to the anterior aspect of the hyoid bone and continuing to the most inferior aspect of the bony chin, then along the symphyseal outline to the tongue tip. *Soft palate area:* outline of the soft palate from posterior nasal spine (PNS). *Oropharyngeal area:* outlined by posterior pharyngeal wall (ppw), dorsal surface of the tongue and soft palate, the superior boundary is a line parallel to 7° to SN plane from PNS to ppw. A line parallel to this and tangential to epiglottic tip forms the inferior boundary. *Intermaxillary space area:* delineated by a trapezium drawn through maxillary and mandibular planes, and points 18 and 1 from Figure 2, after the method by Vig and Cohen.[28] *Tongue proportion*: tongue area as a percentage of the intermaxillary space area

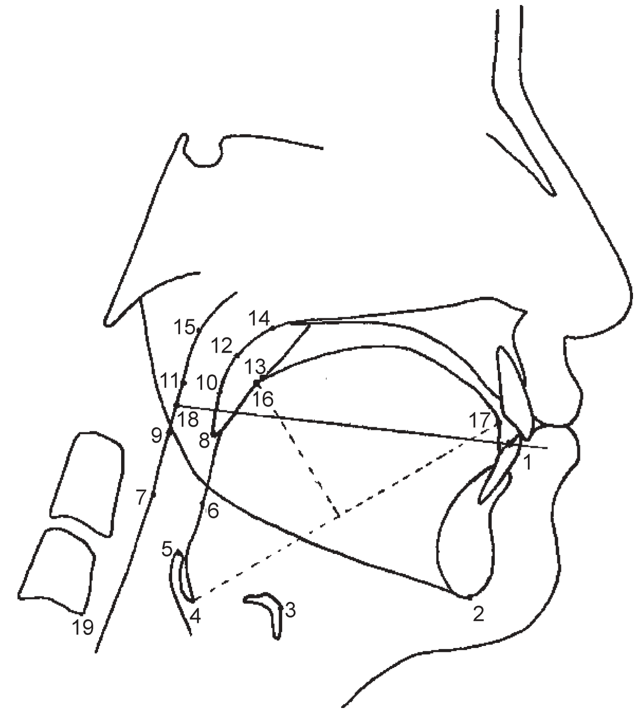

Figure 2 Pharyngeal points and measurements. *Points:* 1, point of intersection of occlusal plane with lower incisor; 2, most inferior point on bony chin; 3, most anterior point on hyoid bone; 4, vallecula; 5, tip of epiglottis; 6, point on tongue where post-lingual airway is narrowest; 7, point on ppw where post-lingual airway is narrowest; 8, tip of uvula; 9, point on ppw horizontally opposite 8; 10, point on soft palate where post-palatal airway is narrowest; 11, point on ppw where post-palatal airway is at its narrowest; 12, point on nasal surface where soft palate is at its thickest; 13, point on oral surface where soft palate is at its thickest; 14, most superior posterior point on soft palate; 15, point on ppw horizontally opposite 14; 16, point indicating tongue thickness (perpendicular to line from vallecula to tongue tip); 17, tip of tongue; 18, point of intersection of occlusal plane with ppw; 19, most inferior anterior point on C3. *Measurements:* Intermaxillary space length, distance between point 18 and point 1; soft palate length, PNS to soft palate tip (point 8); soft palate thickness, points 12 to 13; pharyngeal length, vertical distance between PNS and tip of epiglottis; minimum post-palatal airway, points 10 to 11; minimum post-lingual airway, points 6 to 7; hyoid to ANS, horizontal measure from point 3 to vertical line from ANS

recorded (Figure 1). Magnification was noted and all measurements were converted to life size prior to calculations being performed. Males and females were examined separately.

Statistical evaluation

Comparisons were made between the upright and supine radiographs with the teeth in occlusion, and between the two supine radiographs with the median, range and differences calculated for all the variables. Statistically significant differences were assessed using the Wilcoxon signed ranks test with significance set at the 5% level.

Method error

Twenty upright and 10 supine randomly selected radiographs were re-traced and re-digitized, and random error, systematic error and the coefficient of reliability were calculated.[20,21] Errors were generally less than 1 unit, related mostly to gonion and were slightly greater in the supine films, perhaps due to the poorer quality of these films.

Results

Demographic data

The age at presentation of the 35 patients varied between 29 and 61 years for males, and 28 and 60 years for females, with a mean of 44 years in each group. The mean body mass indices (BMI) for both male (28.4 SD 2.8) and female (26.8 SD 5.3) groups indicate that the majority of patients were overweight although not obese ($BMI = Ht^2/Wt$).

Cephalometric findings

Table 1a,b shows the changes in the oropharynx and associated structures with alteration of posture from the upright to the supine position and with mandibular protrusion in the supine position for males and females, respectively.

Changes with alteration of posture from the upright to the supine position

Oropharynx, soft palate and tongue. We found a significant reduction ($p < 0.01$) in the minimum post-palatal airway for males 1.5 mm (22%) and females 2.4 mm (44%), and there was a significant posterior movement of the soft palate ($p < 0.01$) in the supine position for males and females, demonstrated by a reduction in the horizontal distance between the posterior pharyngeal wall and the posterior nasal spine, and between the posterior pharyngeal wall and the soft palate tip; and an increase in soft palate area ($p < 0.01$). There was no significant change in pharyngeal length with alteration of posture. A supine position increased the proportion of tongue within the intermaxillary space area ($p < 0.01$) and reduced the minimum post-lingual airway for males by 1.9 mm (18%) and females 1.4 mm (22%).

Hyoid. The hyoid moved forward significantly in both groups, as shown by the changes in hyoid to ANS ($p < 0.01$) and hyoid to menton distances. However, vertical hyoid movements were inconsistent and varied between the male and female groups.

Changes with mandibular protrusion in the supine position

Oropharynx, soft palate and tongue. There were few changes in the soft palate region following mandibular procession, namely, in females the thickness of the soft palate reduced, the pharynx opened at the level of the posterior nasal spine and the soft palate area reduced, finally the oropharyngeal area increased. The tongue proportion reduced significantly ($p < 0.01$) in males (18%) and females (17%), and the minimum post-lingual airway was essentially unchanged in both groups.

Table 1a Dimensions of the pharynx and related structures — males (n = 18), median (range)

Variable	Upright	Supine in occlusion So	Diff So–U	Sig.	Supine in protrusion Sp	Diff Sp–So	Sig.
Soft palate length (mm)	38.8 (14.8)	41.1 (18.5)	–0.6	NS	41.6 (18.9)	0.5	NS
Soft palate thickness (mm)	11.2 (25.6)	11.7 (5.3)	0.4	NS	10.9 (6.3)	–0.2	NS
Soft palate area (mm^2)	3.8 (3.0)	5.7 (3.4)	0.8	**	5.2 (3.7)	–0.4	NS
Pharynx at PNS level (mm)	18.3 (10.4)	16.4 (14.6)	–2.5	**	18.1 (9.5)	1.0	NS
Pharynx at soft palate tip (mm)	11.4 (10.9)	8.2 (6.5)	–2.8	**	7.4 (9.7)	–1.0	NS
Pharyngeal length (mm)	53.7 (20.6)	56.0 (18.8)	2.6	NS	55.2 (17.3)	–1.3	NS
Oropharyngeal area (mm^2)	6.1 (4.5)	6.4 (3.9)	0.5	NS	6.8 (3.0)	0.1	NS
Min. post-palatal airway (mm)	6.7 (7.9)	3.9 (6.3)	–1.5	**	4.0 (9.5)	0.0	NS
Min. post-lingual airway (mm)	10.5 (11.5)	7.3 (14.1)	–1.9	*	7.4 (13.0)	0.4	NS
Tongue proportion (%)	91.8 (36.7)	113.6 (47.3)	21.0	**	86.4 (38.3)	–20.4	**
Hyoid–max plane (mm)	73.4 (19.8)	74.4 (20.3)	3.0	NS	77.0 (22.2)	–1.7	NS
Hyoid–mand plane (mm)	19.8 (19.0)	22.0 (23.6)	1.0	NS	18.8 (22.8)	–2.5	*
Hyoid–ANS (mm)	59.5 (32.3)	49.2 (34.3)	–9.6	**	45.6 (36.1)	–1.5	NS
Hyoid–menton (mm)	46.4 (23.9)	38.6 (22.3)	–7.9	**	43.1 (22.4)	4.5	**
Hyoid–C3 (mm)	40.2 (20.1)	38.9 (16.4)	0.4	NS	38.7 (16.4)	0.9	*
Intermaxillary space area (mm^2)	42.1 (18.9)	23.9 (13.8)	–18.4	***	29.1 (13.6)	3.3	**
Overjet (mm)	2.0 (11.9)	2.3 (12.1)	0.4	NS	–3.2 (10.6)	–5.7	**
Overbite (mm)	2.7 (7.2)	1.2 (10.7)	–0.5	NS	–3.9 (6.2)	–4.8	*

Table 1b Dimensions of pharynx and related structures — females ($n = 14$), median (range)

Variable	Upright	Supine in occlusion So	Diff So–U	Sig.	Supine in protrusion Sp	Diff Sp–So	Sig.
Soft palate length (mm)	36.3 (10.8)	37.2 (10.8)	1.6	NS	37.4 (11.8)	–1.0	NS
Soft palate thickness (mm)	9.2 (3.0)	9.3 (2.9)	0.6	NS	8.8 (2.8)	–0.4	*
Soft palate area (mm^2)	3.2 (1.8)	3.7 (2.2)	0.8	**	3.7 (2.5)	–0.3	*
Pharynx at PNS level (mm)	17.2 (9.2)	14.0 (13.0)	–3.8	**	18.2 (10.5)	3.0	**
Pharynx at soft palate tip (mm)	7.6 (6.7)	5.6 (5.9)	–1.6	**	5.7 (7.1)	0.5	NS
Pharyngeal length (mm)	47.4 (21.8)	42.2 (25.3)	–2.6	NS	42.9 (26.9)	–0.9	NS
Oropharyngeal area (mm)	4.7 (3.8)	3.9 (4.3)	–0.6	NS	4.9 (4.2)	0.3	*
Min. post-palatal airway (mm)	5.5 (9.1)	3.3 (5.3)	–2.4	**	3.8 (7.0)	0.1	NS
Min. post-lingual airway (mm)	6.4 (10.0)	5.8 (9.0)	–1.4	NS	6.5 (7.4)	0.7	NS
Tongue proportion (%)	90.7 (56.7)	107.9 (61.9)	11.5	**	88.3 (32.7)	–18.2	**
Hyoid–max plane (mm)	60.2 (21.7)	58.1 (23.4)	–0.9	NS	59.9 (17.8)	1.6	NS
Hyoid–mand plane (mm)	20.1 (20.2)	14.9 (23.1)	–2.8	*	14.1 (32.0)	–1.6	NS
Hyoid–ANS (mm)	60.3 (19.0)	55.6 (30.3)	–7.6	**	57.4 (28.8)	1.7	NS
Hyoid–menton (mm)	44.0 (11.8)	39.8 (14.5)	–4.0	*	43.4 (13.8)	3.2	**
Hyoid–C3 (mm)	32.5 (14.4)	33.8 (14.4)	0.8	NS	34.2 (10.9)	1.4	NS
Intermaxillary space area	33.6 (21.3)	20.1 (13.3)	–12.2	**	22.7 (40.2)	3.2	**
Overjet (mm)	3.0 (9.0)	2.7 (9.6)	–0.2	NS	–0.7 (8.4)	–3.6	**
Overbite (mm)	2.6 (9.1)	1.9 (9.0)	–0.7	NS	–4.2 (7.2)	–6.4	**

(Statistical significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$) For explanation of measurements see Figures 1 & 2

Hyoid. The increase in hyoid to menton distance could suggest that the hyoid moved backwards, however, it must be remembered that the mandible has protruded, which would increase this distance even if the hyoid position remained the same. Similarly, the reduction in hyoid to mandibular plane distance is likely to be due to the mandibular protrusion. The hyoid to C3 distance increased in both groups suggesting that the hyoid moved forwards with the mandible on protrusion, although not to the same extent. Vertical hyoid movements were inconsistent with respect to the static maxilla.

Discussion

The pharyngeal airway has been extensively studied in relation to OSA subjects, most often in the upright position, but there is little information about these parameters in non-apneic snorers. Airway width was assessed by two measurements, the minimum width posterior to the soft palate and base of the tongue. These sites have been most often reported to be narrowed/obstructed in patients prone to sleep related breathing disorders,[6] and it was felt that by always measuring the smallest difference across the pharynx, any overall change, due to the supine posture or mandibular protrusion, would be determined.

Alteration of posture from upright to supine positions

Oropharynx. In our study we have shown that pharyngeal length of the non-apneic snorers did not alter significantly with alteration of posture. This confirms the results of earlier findings. For example, the pharyngeal length has been shown to increase[22] or decrease[17] in OSA studies with change of posture from the upright to the supine position. Non-apneic snorers are thought to have less collapsible pharyngeal muscles than their apneic counterparts,[2] which enables the maintenance of the pharyngeal length in the supine position.[15,22]

Soft palate. Similarly the airway behind the soft palate significantly reduced by 1.5 mm (22%) in males and 2.4 mm (44%) in females. Similar reductions have been shown in studies assessing subjects with OSA.[17,23] Pracharktam *et al.* demonstrated significant reductions in the superior-posterior pharyngeal space with alteration of posture in non-apneic snorers and those with OSA.[11] They also showed significant differences between these two groups in both positions with the OSA group having smaller superior-posterior spaces. The effect of posture on soft palate area, thickness and length is debated in the literature. Johal and Battagel suggested in the upright position the vertical gravitational pull dictates the soft palate size and shape, with change of posture this pull is redirected causing increases in the soft palate thickness and area.[17] Increases in soft palate thickness and area have been demonstrated on subjects with OSA by Yilidrim *et al.*,[23] yet Johal and Battagel showed increases in area only.[17] No significant increases in soft palate thickness or length were seen in this group, but there were significant increases in soft palate area in the supine position and this accords with other work.[15]

Tongue. Pharyngeal occlusion is more likely if the amount of intermaxillary functioning space available for the tongue is reduced, causing it to take up a more posterior position and reducing the posterior airway dimensions. Pae *et al.* demonstrated backward movement of the posterior aspect of the tongue with alteration of posture to the supine position in subjects with OSA.[14] However, Miyamoto *et al.* demonstrated this movement only in subjects with non-apneic snoring and not in those with OSA suggesting that awake subjects with OSA maintain an upright tongue posture in order to protect their airways.[24] This present study demonstrated a reduction in the pharyngeal airway behind the tongue, whilst supine in non-apneic snorers.

Tongue proportion is the percentage of intermaxillary space (IMS) occupied by the tongue. Vig and Cohen originally stated that the tongue proportion for erect adults was 67%,[25] but higher values have been described of 91% for OSA subjects and 83% in simple snorers.[15] It can be seen from this present study that a supine position increases the tongue proportion significantly to 103% in males and 107% in females and tends to reduce the minimum distance between the posterior pharyngeal wall and the tongue by 30% in males and 9% in females. This tendency to a reduction in pharyngeal airway behind the tongue in patients with non-apneic snoring is similar to that seen in subjects with OSA as suggested by Pracharktam *et al.*[11] and Johal and Battagel,[17] but is at variance with work by Eveloff *et al.*[26] One reason for this discrepancy, suggested by Johal and Battagel,[17] may be that these latter authors did not control the phase of respiration during which the films were taken and that the exact level at which the measurements are taken depends heavily upon the horizontal plane used to orientate the film.

Hyoid. The hyoid moved anteriorly in this sample, which supports work on snorers and subjects with OSA.[11,17] Pae *et al.* demonstrated that the hyoid is lower in apneic than non-apneic snorers whilst upright.[14] Vertical movements of the hyoid with alteration of posture were inconsistent and insignificant in this study.

The effect of mandibular protrusion

Oropharynx. The oropharyngeal area increased only in females with mandibular protrusion. Previous supine cephalometric studies on subjects with OSA agree that oropharyngeal areas increase on mandibular protrusion.[16,17] Ferguson *et al.* using videofluoroscopy demonstrated increases in oropharyngeal and hypopharyngeal cross-sectional areas in awake, supine, subjects with OSA on maximum protrusion with no significant increase in velopharyngeal size.[27] However, Ryan *et al.* using the same technique, failed to show changes in oropharyngeal size and suggested that the MAS increased the lateral more than the anterior-posterior diameter of the velopharynx and it was this that was responsible for the reduction in AHI associated with wearing the MAS.[18] A computer tomographic study by Gale *et al.* demonstrated an increase in the minimum pharyngeal cross-sectional area with use an anterior mandibular positioning appliance.[19]

Soft palate. The post-palatal airway did not increase significantly with mandibular protrusion in this study. Previous studies with this appliance suggest increases of 22%[17] to 47%[16] in subjects with OSA. The reason for this difference may be the less compliant pharyngeal tissues of non-apneic when compared to apneic snorers.[2,28]

Tongue. Battagel *et al.* suggested that for any mandibular advancement device to prevent pharyngeal occlusion, the functioning space available for the tongue must be improved.[16] This study demonstrates significant increases in intermaxillary area with mandibular protrusion of 18% in males and 17% in females. The proportional relationship of the tongue to the functioning space is therefore reduced by a similar degree. This supports work by Battagel *et al.* who showed similar increases using a MAS in patients with OSA.[16] The post-lingual airway was essentially unchanged for both groups. Greater changes, with increases in the size of the post-lingual airway with use of a MAS, have been shown in subjects with OSA.[16] This may be due to the less compliant airways of the non-apneic snorers responding less well to protrusion or it may be a reflection of the smaller sample size used in this study.

Hyoid. In the horizontal direction, measurements of the hyoid in relation to the mandible would suggest that the hyoid moved backwards. However, it must be remembered that the mandible is in a protrusive position, which would also cause an increase in hyoid to mandible values if the hyoid position remained unchanged. The hyoid to C3 distance increased with protrusion in males and females (significant only in males), which would suggest that the hyoid moved forwards with the mandible, although not to the same extent. Vertically, the hyoid appears to move upwards in relation to the mandible, but movement is inconsistent in relation to the static maxilla. On protruding the mandible, however, there would be some degree of opening, which may confound these results. This diverse range of vertical movement for the hyoid has been noted in previous studies on subjects with OSA.[16] Suggestions for these results have included the posterior repositioning of the tongue to accommodate the inter-occlusal wax record for the protrusive film and not all the films being exposed at the end of expiration, as the hyoid is sensitive to changes in the respiratory cycle.[16]

A low hyoid position has been described as one of the distinguishing cephalometric features of OSA[5] and it has been considered to be a poor prognostic indicator for the use of mandibular advancement splint therapy.[26] Comparing the relative positions of the hyoid in these non-apneic snorers with hyoid positions in subjects with OSA[16] suggests that in the supine position the hyoid is more anterior and closer to the mandible in these patients. This would support authors who suggest that treatment with a MAS is better suited to those with mild sleep-related breathing disorders than those with more severe disease.[29]

Limitations of the study

This study has some limitations. The small sample size number is a reflection of the problems encountered in taking lateral supine radiographs and this may have influenced the significance of the results. The pharyngeal dimensions measured were of awake subjects. It is known that the effect of sleep plays a significant role on pharyngeal size. Malhotra *et al.* demonstrated a significant increase in collapsibility during sleep of normal and apneic subjects.[30] However, they showed that there was a significant correlation between collapsibility during wakefulness and sleep, suggesting that measuring the pharyngeal airway whilst awake still provides useful information about pharyngeal mechanics whilst asleep.

Conclusions

- A supine posture results in significant reductions in pharyngeal airway measurements of non-apneic snorers.
- Mandibular protrusion in the supine position leads to an increase in the functioning space for the tongue.

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Authors and Contributors

JB was responsible for the conception and design of the studies. The data was collected by AMS. Both JB and AMS were responsible for the analysis and interpretation of the data. AMS drafted the articles, which were revised by JB. Both JB and AMS approved the final version of the article to be published. JB is the guarantor.

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