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Airway morphology and its influence on OSA severity and surgical intervention: a retrospective study

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Introduction: The aim was to assess the relationship between airway morphology and surgical intervention in a cohort of patients presenting with increased body mass index (BMI) and a confirmed diagnosis of obstructive sleep apnoea (OSA). A secondary aim was to revisit the relationship between morphology and OSA severity.
Methods: A retrospective analysis was conducted of pre-operative maxillofacial 3D-CT scans of thirty-two patients with a confirmed diagnosis of OSA who received treatment from an ear nose and throat specialist (ENT). Lateral cephalograms were imported into Quick Ceph Studio (Quick Ceph Systems Inc, San Diego, CA, USA) after which linear and angular measurements of selected hard and soft tissues were obtained. 3D-CT images were loaded into the software program 3dMDVultus (3dMD) which permitted 3D visualisation of the airway. Measurements were repeated 3 times on the images of six patients after an interval of two weeks to establish the intraclass correlation coefficient (ICC) for intra-examiner accuracy and reliability. Logistic regression was applied to determine the relationships between morphology, OSA and surgical treatments.
Results: A positive correlation was found between age and the apnoea-hypopnea index (AHI). Morphological measurements of the airway did not exhibit a positive relationship with OSA severity. Posterior airway space at the level of the uvula and tongue, the length of the soft palate and position of the hyoid bone were significantly associated with BMI. No variables were found to be correlated with uvulopalatopharyngoplasty (UPPP) surgery. Notwithstanding, airway length and posterior airway space at the level of the uvula tip were significantly associated with tongue channelling.
Conclusions: Radiographic airway assessment is an invaluable and opportunistic tool for screening OSA but requires judicial use in its prescription and interpretation. There is little correlation between OSA severity and airway morphology and between surgical intervention and morphology. Additional factors need to be considered before a treatment modality is considered and is best managed in a multidisciplinary setting.
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Introduction

Obstructive sleep apnoea (OSA) is a well known and common sleep-related breathing disorder characterised by upper airway resistance leading to obstruction and repeated sleep fragmentation. Due to its impact on quality of life and its association with many comorbidities, OSA is recognised as a serious public health issue by governments worldwide.[1] As the aetiology of OSA is multifactorial, there is broad interest across many health professions.

Of the professions, orthodontics is well suited to managing OSA because a large component of practice revolves around treatment using dento-facial orthopaedics. Craniofacial disproportion in skeletal retrognathia of one or both jaws, dolicocephalic headform, constricted maxillae and open bite tendencies are among the reported characteristics that can predispose to OSA. Alarmingly, a large proportion of patients exhibiting the characteristics of OSA remain undiagnosed.[2,3] Given the focus on the craniofacial complex and the routine diagnostic processes undertaken during treatment planning, orthodontists are primed to identify these factors.

One area of interest is the assessment of airway morphology and OSA severity based on the apnoea-hyponea index (AHI). Many studies have investigated the association between airway shape, volume, cross-sectional area and diameter with AHI based on 2D and 3D radiographic imaging. Despite this, the reported associations are wide-ranging from little to statistical significance.[4–10] Common areas of focus include the assessment of the posterior airway space, tongue size, adenoid mass, minimum cross-sectional area and soft palate length from cephalometric and cone beam analysis. However, once these parameters were identified, there is less guidance regarding the best course of action. This may be partly due to a paucity of research correlating morphology with actual treatment requiring a multidisciplinary emphasis. The deficiency in co-ordinated care is a problem identified by all health professions involved with OSA.

The problem has recently been identified by the American Association of Orthodontists (AAO) citing a lack of consolidated guidelines. The AAO therefore established a task force to review protocols for OSA and resulted in the publication of the AAO whitepaper as an authoritative guide for orthodontists.[11] The underpinning AAO philosophy is the multidisciplinary management of OSA under the guidance of a medical specialist.[11]

Among the medical specialties, a significant proportion of an ENT surgeon's clinical practice is devoted to patients presenting with sleep-related breathing issues with the most common being OSA.[12] Kizirian et al. estimated that almost one-third of referred patients to an ENT surgeon exhibited sleep disorders.[13] With many options in the ENT's treatment armamentarium, clinical judgement is required to determine whether surgery and its nature, is appropriate. The challenge in managing OSA is due to the heterogeneous nature of the disease as the differential diagnosis of airway obstruction is not singular but rather diverse and complex.

In line with AAO's recently reported principles of OSA management, there is a benefit in identifying those factors which might influence a medical specialist to consider surgical intervention. Awareness of these factors might ultimately improve communication, triage, consent, and the management of OSA between health professionals in a co-ordinated effort. Therefore, the present study has a multidisciplinary focus and a primary aim to assess the relationship between morphology and surgical intervention in a cohort of patients presenting with an increased BMI and a confirmed diagnosis of OSA. A secondary aim is to revisit the relationship between morphology and OSA severity.

Methods and materials

This was a retrospective study focusing on patients previously diagnosed with moderate to severe OSA and who had seen and received surgical treatment by an Ear Nose Throat (ENT) specialist practising in Perth, Western Australia. Ethics approval for the study was obtained from the Human Research Ethics Committee of The University of Western Australia (RA/4/1/5392).

Data collection and imaging sources

The present study consisted of consecutive records of the most recent 32 patients (26 males and 6 females) with a diagnosis of moderate (apnea-hypopnea index (AHI) ≥ 15) to severe OSA (AHI ≥ 30) presenting and receiving surgical treatment by an ENT surgeon. All patients were within the age range of 30 to 63 years; had body mass index (BMI) in the overweight range (BMI ≥ 25); exhibited an AHI ≥ 15 per hour of sleep; and had a pre-surgical low dose CT scan. The mean BMI was 30.7 and 29.7 for males and females, respectively. Patient-specific data concerning polysomnography, age, gender, height, BMI and the type of ENT procedure were obtained from the surgeon.

For each patient, the pre-treatment 3D-CT scans obtained from the same radiological clinic were

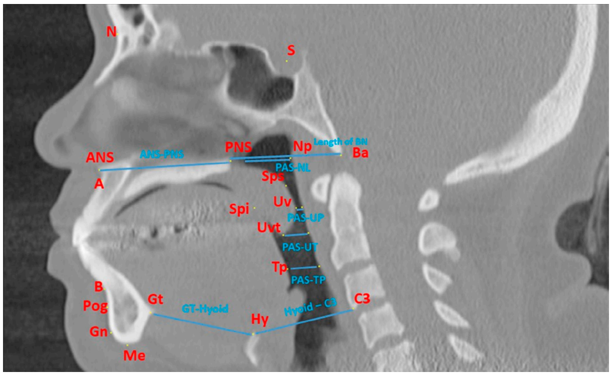

Figure 1. Quick Ceph Studio, San Diego, CA. Cephalometric landmarks and reference lines (mm). S (sella), centre of sella turcica; N (nasion), V notch of frontal and nasal bones; A point, deepest point between ANS and upper incisor alveolus; B point, deepest point between pogonion and lower incisor alveolus; Ba (basion), most inferior point of occipital bone; ANS, tip of anterior nasal spine; PNS, tip of posterior nasal spine; Pog (Pogonion), most anterior point of symphysis; Me (menton), most inferior point of symphyseal outline; Gn (gnathion), most anterior and inferior point on bony chin; Gt (genial), most posterior point of genial tubercle; Hy (hyoid body), most antero superior point of the hyoid bone; Uvt (Uvula tip), most posterior inferior point of the uvula; Uv (Uvula), most posterior point of uvula; PAS (pharyngeal airway space); NL (nasal line); PAS-UP, minimal PAS between uvula and posterior pharyngeal wall; PAS-UT, minimal PAS between uvula tip and posterior pharyngeal wall; PAS-TP, minimal pharyngeal airway space between back of tongue and posterior pharyngeal wall; ANS-PNS, distance from ANS to PNS; Length of BN, PNS to basion; Hyoid-C3, distance between C3 (anterior and inferiorly) and hyoid (antero-superiorly); GT-hyoid, genial tubercle to hyoid distance; Length SP, distance from PNS to tip of uvula (midline); SP thick, maximum thickness of soft palate measured perpendicular to PNS to uvula line.

sourced and a lateral composite image was generated. The images were digitally stored in DICOM (Diagnostic Imaging and Communications in Medicine) format.

2D measurements

The lateral head images were imported into *Quick Ceph Studio* software (Quick Ceph Systems Inc, San Diego, CA, USA). The radiographs were orientated such that the maxillary plane was parallel to the horizontal plane. Conventional landmarks were identified and a subsequent cephalometric analysis involving linear and angular measurements was performed by a single operator (Figure 1).

3D measurements

DICOM CT images for each patient were loaded into 3dMDVultus (3dMDVultus software, 3dMD, Atlanta, GA), and a semi-assisted software program provided 3D visualisation of the airway (Figure 2). This formed the basis of the morphological analysis. The patient's orientation was corrected prior to airway analysis, with the head centred and positioned so that the palatal plane was parallel to the horizontal plane. The

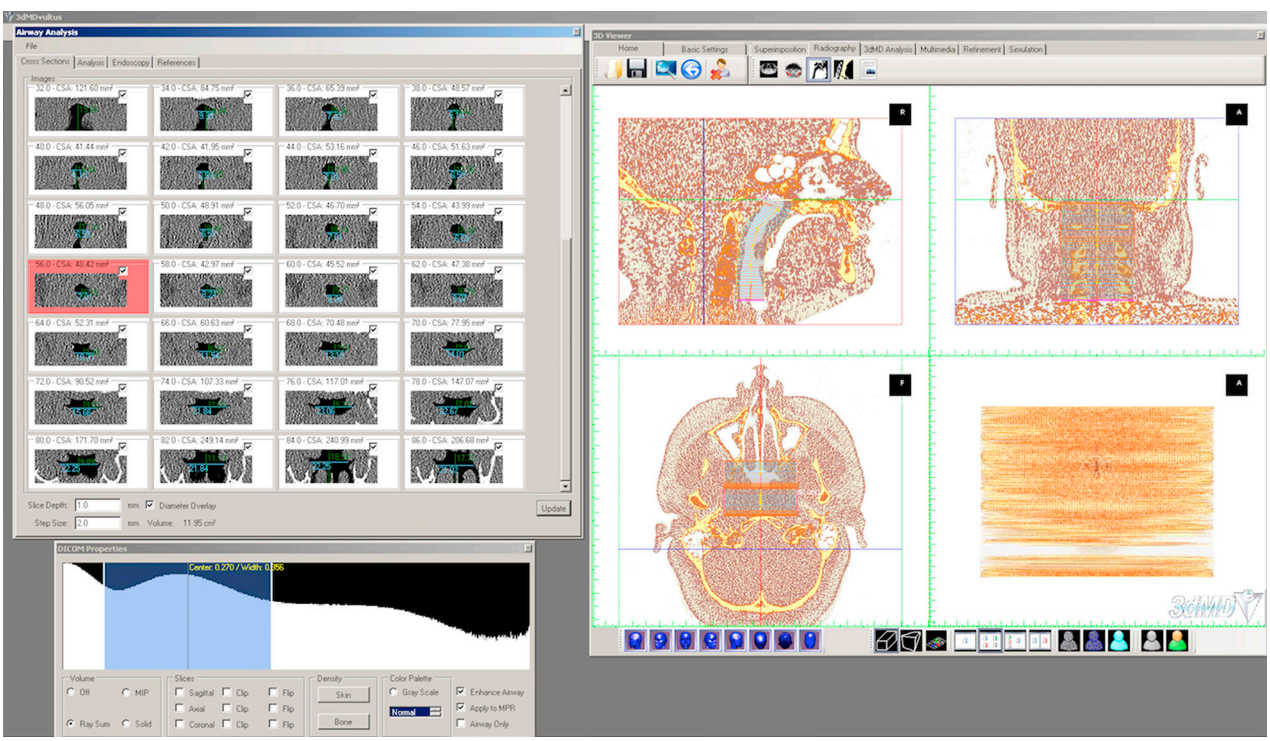

Figure 2. 3D Measurements (3dMDVultus software, 3dMD, Atlanta, GA).

Table I. Descriptive statistics.

	Total			Male			Female		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
BMI (kg/m²)	22	30.4	3.8	16	30.7	3.4	6	29.7	5.2
Cross SA (mm²)	32	51.2	25	25	56	24.4	6	34.7	22.1
ML Diameter	32	14.2	8.97	25	13.25	4.96	6	19.31	18.3
AP Diameter	32	3.48	3.6	25	3.72	3.84	6	2.81	2.79
Volume (cm³)	32	12.8	7.3	25	13.6	7.6	6	9.9	6
Length (mm)	32	83.4	7.9	25	84.2	7.1	6	80.3	11.3
SNA (deg)	32	81.9	5.1	25	81.8	4.5	6	80.1	5.7
SNB (deg)	32	78.9	5.2	25	78.9	5.2	6	77.3	4.3
ANB (deg)	32	3.6	2	25	3.8	2.1	6	2.6	1.4
PAS-NL (mm)	32	23.8	3.8	25	24.2	3.9	6	21.8	3.8
PAS-UP (mm)	32	3.4	2.4	25	3.6	2.6	6	2.5	1.3
PAS-UT (mm)	32	7.6	3.7	25	7.9	4	6	5.8	2.1
PAS-TP (mm)	32	9.7	5.5	25	9.8	5	6	9.7	7.9
Length BN (mm)	32	42.5	4.9	25	42.9	5.1	6	41.3	4.6
ANS-PNS (mm)	32	51.6	6.5	25	53.2	6.1	6	45.4	4
HYOID C3 (mm)	32	37.2	6.6	25	38.5	6.7	6	32.8	3.9
GT HYOID (mm)	32	39.3	5.3	25	40	5.4	6	36.6	4.8
Length SP (mm)	32	39.7	8.3	25	40.5	8.2	6	36.6	9.6
SP thick (mm)	32	11.2	1.9	25	11.4	1.5	6	10.3	3

airway was outlined by a measurement grid, from the lowermost border of C4 extending to the palatal plane (ANS-PNS), defined visually by the investigator.[14] A 2 mm distance slice along the airway was determined, and measurements of cross-sectional areas and linear dimensions in two directions (anteroposterior and mediolateral) were calculated by the software for each slice from the axial view. Although maximum and minimum cross-sectional areas were identified, only the minimum value was recorded. In addition, measurements of airway length and total airway volume was determined by the software.

Reliability of measurements

The accuracy and reliability of 3D airway analysis using 3dMDVultus software were previously documented by Schendel and Hatcher.[15] In the present study, to test the reliability of measurements, 6 patient's images were randomly selected and measurements were repeated by the same operator 3 times at two-week intervals. The intraclass correlation coefficient (ICC) was used to assess the consistency of quantitative measurements. The results were highly reproducible, with the lowest ICC of 0.883 for airway length, and the remaining measurements ranged from 0.97 to 0.999.

Statistical analysis

Statistical analyses were performed using the R statistical computer software (R version 3.0.0). Descriptive statistics were analysed for each variable and sample mean values were determined for gender (Table I). The relationships between AHI and BMI with other variables were tested using simple linear regression. A multiple regression analysis was applied to determine the association of volumetric and morphological findings with the severity of OSA and prediction of BMI. Additionally, the connection between the types of treatment proposed with other variables was evaluated using logistic regression. An accepted P value of < 0.05 was applied to determine statistical significance.

All measurements were represented in millimetres, angles between lines in degrees and individual areas in square millimetres. Descriptive results were depicted as mean ±SD.

Results

Sample population

Table I outlines key descriptive statistics relating to airway measurements of the cohort of 32 obese patients with a history of OSA.

OSA severity and upper airway measurements

The relationship between AHI with other variables was tested using simple linear regression. Of the variables which included age, gender and airway measurements (linear, angular, cross-sectional area and volumetric), only age was significantly associated with AHI (P = 0.0161) (Table II).

A multiple regression was fitted using the volumetric and morphological measurements of the airway

Table II. Relationship between OSA, BMI and other variables.

	Obstructive Sleep Apnoea		**Body Mass Index**	
Variable Category	Coefficient	p-value	Coefficient	p-value
Patient				
Sex	-0.607	0.9555	1.022	0.591
Age	1.183	**0.0161 ***	-0.017	0.8637
BMI	0.954	0.5035	0.024	0.5035
3D Morphology				
Cross-sectional Area (mm^2)	-0.113	0.5172	0.001	0.9802
ML Diameter (mm)	0.032	0.9476	-0.11	0.1924
AP Diameter (mm)	-0.149	0.9001	0.339	0.153
Volume (cm^3)	-0.614	0.3156	-0.036	0.7335
Length (mm)	-1.039	0.0751	-0.152	0.1603
2D Angular				
SNA	0.957	0.3126	0.158	0.3699
SNB	0.983	0.2754	0.268	0.1006
ANB	-0.6	0.8023	-0.332	0.4512
2D Linear				
PAS-NL	-0.738	0.5182	0.132	0.5572
PAS-UP	-1.408	0.4375	0.63	**0.0418***
PAS-UT	0.17	0.8852	0.35	0.1352
PAS-TP	-0.037	0.9632	0.37	**0.0068 ***
Length of BN	-0.941	0.3443	0.244	0.207
ANS-PNS	-0.389	0.6317	0.082	0.5711
HYOID-C3	0.023	0.9751	0.355	**0.0034 ***
GT-HYOID	0.623	0.4508	0.357	**0.026 ***
Length SP	-0.435	0.4788	0.242	**0.0268 ***
SP thick	1.939	0.4016	1.939	0.4016

Table III. Predicting key variables using multiple regression analysis.

Obstructive Sleep Apnoea (Moderate to Severe)				
	Coefficient	Std. Error	t value	p-value
(Intercept)	-159.404	90.859	-1.754	0.0933
AP Diameter	2.655	1.596	1.663	0.1104
SNA	2.99	1.114	2.685	0.0135
ANB	-3.729	2.492	-1.496	0.1488
PAS-UP	-4.916	2.526	-1.946	0.0645
Length of BN	-1.778	1.012	-1.757	0.0928
SP thick	4.072	2.291	1.778	0.0893
R^2=0.3182, p-value: 0.1655				

Body Mass Index				
	Coefficient	Std. Error	t value	p-value
(Intercept)	-3.05286	5.09058	-0.6	0.5577
Cross-sectional Area	-0.14134	0.02645	-5.344	<0.0001
ANB	-0.77577	0.2616	-2.965	0.0096
PAS-NL	0.46682	0.14898	3.134	0.0068
PAS-UT	0.57712	0.14678	3.932	0.0013
HYOID-C3	0.18169	0.08468	2.146	0.0487
GT-HYOID	0.52891	0.10859	4.871	0.0002
R^2=0.8166, p-value: <0.0001				

(Table III). Using backwards selection and a variable selection cut-off of p-value < 0.05, none of the variables was noted as a significant predictor of AHI.

Relationship between BMI and other variables

Despite all patients exhibiting a high BMI, there was no correlation with BMI and severity of disease based on AHI ($p = 0.5035$).

The relationship between BMI and other variables was tested using simple linear regression (Table II). Cross-sectional linear measurements at different levels of the airway, PAS-UP ($P = 0.0418$), PAS-TP ($P = 0.0068$), HYOID-C3 ($P = 0.0034$), GT-HYOID ($P = 0.0260$) and Length SP ($P = 0.0268$), were significantly associated with BMI.

A multiple regression was also fitted to all volumetric and morphological measurements (Table III). Variables were selected using a backward variable selection process and a cut-off p-value of 0.05. It was found that cross-sectional area ($P < 0.0001$), ANB ($P = 0.0096$), PAS-NL ($P = 0.0068$), PAS-UT ($P = 0.0013$), HYOID-C3 ($P = 0.0487$) and GT-HYOID ($P = 0.0002$) together provided the best prediction for BMI.

Relationship between uvulopalatopharyngoplasty (UPPP) and tongue channelling (TC) surgery and variables

A list of treatments performed for each patient is shown in Table IV. Table V outlines the relationship between two common procedures, uvulopalatopharyngoplasty (UPPP) and tongue channelling (TC), with airway morphology.

No variables were statistically associated with receiving UPPP. Airway length, PAS-UT was associated with TC surgery ($P = 0.0132$ and $P = 0.0485$, respectively). In addition, cross-sectional area, airway length and PAS-UT were found to be significant predictors of TC treatment (Table VI). It is important to note that in this cohort, three patients were treated with UPPP alone while eight patients were treated with UPPP in combination with other surgical procedures such as septoplasty, lingual tonsillectomy and trans-palatal advancement. All cases of TC were performed in combination with UPPP and/or trans-palatal advancement.

Discussion

Relationship between age and increased AHI

The association between increased age and AHI is consistent with previous published studies.[16–18] Although the mechanisms are not fully understood, the most widely accepted proposition suggests that aging impacts on airway anatomy, by an increase in pharyngeal fat deposition and a reduced control of the pharyngeal dilator muscles. Malhotra et al. examined a group of mixed subjects with normal BMI (<30) separated by age (35 year group vs 65 year group) and demonstrated that fat deposition, lengthening of the soft palate and a reduction in airway dimensions occurred as a function of increased age.[17] These outcomes occurred independent of BMI, suggesting a process related to physiological maturation. Other studies associated longer airway length with OSA in older individuals.[10,19,20] An additional factor is the aging effects on sensorimotor impairment, a reduction in neuromuscular control and the degradation of protective airway reflexes.[21] Anatomically, there are reports linking an age-related reduction in genioglossus activity as a contributory factor to pharyngeal collapse.[17]

In concert, many studies have demonstrated a wide range of age-related effects and their association with OSA. While the impact and contribution of each of these factors are not well understood, aging is foremost a non-modifiable risk factor that can affect the success of short to medium-term treatments.

Relationship between BMI, airway and AHI

Of all known risk factors for OSA, obesity is perhaps the most investigated. Many cross-sectional studies have consistently demonstrated a relationship between increased body mass and OSA.[18] Estimates place significant OSA in 40% of obese individuals and approximately 70% of patients with OSA are obese.[22] In a prospective study by Peppard et al., a

Table IV. List of treatment for each patient.

Treatment done	Patients (N)
CPAP only	3
CPAP + Septoplasty	3
Maxillo advancement surgery	1
Septoplasty	1
UPPP + Septoplasty	1
UPPP	3
UPPP + lingual tonsilectomy	1
UPPP + Transpalatal advancement	6
UPPP + tongue channelling + transpalatal advancement	10
UPPP + tongue channelling	3

Table V. Relationship between surgical procedure and other variables.

	Uvulopalatopharyngoplasty		Tongue Channelling	
Variable Category	Odds Ratio	p-value	Odds Ratio	p-value
Patient				
Sex	2.111	0.4664	1	1
Age	0.91	0.1003	1.017	0.7039
BMI	1.049	0.7136	0.889	0.3506
AHI/RDI	0.97	0.137	0.987	0.4605
3D Morphology				
Cross-sectional Area (mm^2)	1.007	0.7036	0.964	0.1086
ML Diameter (mm)	1.03	0.7204	0.939	0.3984
AP Diameter (mm)	0.991	0.9342	0.758	0.1395
Volume (cm3)	1.206	0.1341	1.073	0.2565
Length (mm)	1.163	0.0515	1.219	**0.0132 ***
2D Angular				
SNA	0.923	0.341	0.965	0.6372
SNB	0.97	0.6967	0.937	0.39
ANB	0.789	0.2732	0.922	0.6657
2D Linear				
PAS-NL	0.862	0.2475	1.079	0.484
PAS-UP	1.097	0.6425	0.756	0.2213
PAS-UT	1.159	0.256	0.765	**0.0485 ***
PAS-TP	1.188	0.0994	0.956	0.5316
Length of BN	0.915	0.2936	1.047	0.5454
ANS-PNS	0.977	0.7112	0.96	0.4946
HYOID-C3	0.967	0.595	0.896	0.1047
GT-HYOID	0.929	0.3763	0.899	0.1545
Length SP	1.025	0.6604	1.01	0.8414
SP thick	0.91	0.6893	0.776	0.2509

10% weight gain was associated with a 6-fold increase in the probability of developing OSA.[23] Other studies reported similar characteristics including a positive correlation between fat distribution in the neck and increased AHI.[24–26]

Specific morphological traits in the airway have been associated with increased BMI. Several investigations, including Rodenstein et al.[7] and Schwab et al.,[27] demonstrated that patients with OSA had a predominant pharyngeal dimension in the anterior-posterior axis as opposed to control subjects without a sleep disorder exhibiting a predominant transverse axis.[28] At the very least, this provides a foundation for lateral cephalometric analysis as a screening tool. The underlying mechanisms involved have been attributed to the pattern of fat infiltration around the airway and the influence of the dilator reflexes in awake patients.[29] Despite the increased BMI of patients examined in the present study, BMI was not correlated with the severity of OSA

($P = 0.5035$), a finding which was in contrast to previous studies.[18,24,30] In additional studies, Tsuchiya demonstrated that the anatomical features in obese patients were not necessarily characteristic of OSA by observing two types of OSA patients.[31] In the first group, it was demonstrated that OSA patients presenting with a high AHI and a low BMI tended to have skeletal abnormalities (craniofacial retrognathia) while patients with a low AHI and high BMI tended to exhibit soft tissue changes directed at increased soft palate volume and lower hyoid bone position.[31] Within the latter group, the increase in soft tissue characteristics was highly variable within individuals. In the current study, airway measurements were significantly associated with a high BMI including PAS-UP, PAS-TP, Length SP, Hyoid-C3 and GT-Hyoid, yet, were not significantly associated with OSA severity.

It is worthwhile to speculate why BMI was not correlated with OSA severity in the present study. A possible explanation for this outcome was that all patients participated in weight loss programs required by the ENT surgeon before surgical intervention, underscoring the significance of weight loss in combatting OSA.[32] Additionally, the pathogenesis of OSA is multifactorial and its expression in certain individuals is highly variable.[33] Finally, Mayer demonstrated that the architecture of the pharyngeal lumen was influenced by a combination of BMI and reflexes while patients were awake including the time of CBCT exposure.[28]

Relationship between airway measurements and AHI

Measurements of the upper airway were consistent with published research investigating potential correlations with OSA. The calculated mean of the velopharyngeal airway [PAS – UP] in the present study was smaller compared to controls of similar non-OSA patients suggesting that airway narrowing may be a risk factor for OSA.[34,35] Reports of increased length and width of the soft palate leading to reduced minimal cross-sectional airway in OSA patients was also featured in the present study and consistent with Walsh et al.[9] These authors concluded that the minimal cross-sectional area in the velopharyngeal region was significantly reduced in OSA patients compared with matched controls.[9] Similarly, Johal et al. compared patients with OSA and a control group and found that soft palate length was significantly increased ($P < 0.001$) in the former (43.2 ± 4.7) compared to the latter (35.7 ± 5.8); and soft palate thickness was also increased ($P < 0.001$) in OSA patients (10.6 ± 1.7; 9.5 ± 1.8).[36] An additional study by Rodenstein et al.[7] employed MRI volumetric analysis and identified tongue size as a major determinant of OSA although this finding was not universally shared.[37] The present results agreed with the former as the mean measurement from the most posterior surface of the tongue to the posterior pharyngeal wall was comparatively reduced compared to published control data.[19]

Despite these similarities, the present study showed no statistically significant correlation with airway measurement and increased AHI. This may be attributed to the study methodology and the multi-faceted nature of OSA. Reports consistently show significant variation in upper airway shape and soft tissue coverage between individuals.[28] Stratemann et al.[38] using 3D airway analysis demonstrated significant variability in upper airway morphology, luminal shape and soft tissue outline within the same individual. Exposing CBCT in the supine position in which a lateral cephalogram was constructed does not physiologically replicate the actual condition of the upper airway and associated reflexes, or lack of, during sleep.[39] Static images derived from CBCT scans do not realistically represent the dynamic and dysfunctional nature of OSA. Non-anatomical parameters such as neuromuscular function, ventilatory response and arousal thresholds are potential implicating factors that are not quantified from morphological assessment.

Table VI. Volumetric and morphologic variables and tongue channelling surgery.

Volumetric Measurements

	Coefficient	Std. Error	t value	p-value
(Intercept)	-21.33241	8.85015	-2.41	0.0159
Cross-sectional Area	-0.05826	0.02799	-2.081	0.0374
Length	0.28107	0.10884	2.582	0.0098

Morphological Measurements

	Coefficient	Std. Error	t value	p-value
(Intercept)	8.37026	3.92575	2.132	0.033
PAS-UT	-0.36943	0.17189	-2.149	0.0316
GT-HYOID	-0.15917	0.08435	-1.887	0.0592

Relationship between airway dimensions and patient selection for surgical treatment

Patients involved in the present study had undergone not only one but a combination of different surgical procedures. PAS-UT and airway length were shown to be significantly associated with patients who received tongue channelling surgical treatment; and some measurements were found to be significant predictors of tongue channelling including airway length, PAS-UT and cross-sectional area. This was based on a comprehensive ENT examination including the evaluation of the airway using optic nasendoscopy enabling a detailed subjective assessment of the airway and surrounding soft tissues. These factors likely led to the decision for surgical intervention. Despite this, the findings of the present study do not support advocating treatment based on morphology alone.

A limitation of the present study was the small sample size, a lack of objective parameters leading to the decision to provide a surgical procedure and a non-OSA control group. BMI data from the surgeon consisted only of those with high BMI and the data were not amenable to division into age groups or based on severity. This would have permitted a more meaningful analysis against other factors. Furthermore, soft tissue characteristics would be more accurate if the airway was captured while patients were asleep to represent the expected reduction in pharyngeal muscle activity and reflexes. Additionally, attempts to standardise breathing during the procedure is a consideration. A study with these features would be a closer representation of the dynamic and dysfunctional nature of OSA. A greater qualitative focus involving more specialists would provide additional insight for referring health professionals to identify factors which might predispose the prescription of a particular treatment modality. An ideal situation would be for the primary clinician to screen for risk factors and to better predict and appreciate more targeted strategies for the individual. This would improve the initial examination, communication, informed consent, triage, and referrals and represents the AAO's ultimate philosophy of managing OSA.[11]

Implications in orthodontics and treatment planning

In principle, airway assessment from 2D and 3D radiographic imaging obtained as part of orthodontic treatment planning is an opportunistic and invaluable screening tool for OSA. However, other clinically related factors need to be considered before a treatment modality is proposed. The judicial use of 3D imaging is recommended rather than the blanket prescription of high-dose imaging for the sole purpose of diagnosing OSA. The study is confirmational in that morphology does not reflect OSA severity based on AHI. Additionally, there is little correlation between the range of treatments provided by a medical specialist and morphological assessment. Therefore, potential risk factors identified from imaging should raise the index of suspicion and prompt referral to a medical specialist for multidisciplinary co-ordinated care, in line with the AAO's principles of OSA management.

Conclusion

The aetiology of OSA is complex and multifactorial in which known risk factors and their relative contribution to this sleep disorder vary between individuals. In a group diagnosed with increased BMI and moderate to severe OSA, airway measurements and morphology had little correlation to OSA severity based on AHI even though some characteristics were observed. There was also a limited correlation between actual treatment provided by a medical specialist and airway assessment from 2D and 3D imaging. Therefore, additional factors need to be considered before a treatment modality is proposed. Of all variables assessed, the present study confirms the significant association between increased age and OSA severity. The judicial use of radiographs is recommended and, when available, is an invaluable screening tool to identify individuals at risk of OSA which should prompt referral to a medical specialist for multidisciplinary co-ordinated care.

Conflict of Interest

The authors declare that there is no conflict of interest.

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