REVIEW ARTICLE

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Lateral cephalometric radiograph analysis on obstructive sleep apnea patients

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ABSTRACT

Objectives: This review article is aimed to investigate changes in anatomical factors in Obstructive Sleep Apnea (OSA) patients through means of a cephalometric radiograph, which covers relation and size.

Review: This literature review used online databases (PubMed and Scopus) discussing obstructive sleep apnea (OSA) in adults aged 18-80 years, using cephalometric analysis, and several keywords such as "obstructive sleep apnea and cephalometry" were employed to do the literature search. The search was limited to full-text articles written in English and published during the 2011-2021 period. Articles were selected by complying with literature review guidelines.

Conclusion: Dentists can detect OSA early through lateral radiograph, which is originally an early screening tool, by paying attention to patients' position during exposure, irradiation condition (kV, mA and Sec) and patient position in OSA diagnosis in regards to hard and soft tissue being evaluated. The specific craniofacial morphological variable could be a reliable parameter in determining the existence of OSA.

Keywords: *Cephalometry, obstructive sleep apnea, airway*
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INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep disorders that involves breathing problems in adults, characterized by collapse of the upper airways during sleep, which leads to oxygen desaturation.[1–3] OSA is a major public health challenge today because it is a commonly found chronic disease, but has a negative impact on the health and quality of life of millions of people worldwide.[1,3] OSA affects all age groups with a reported prevalence of around 2-5% in adults worldwide.[4] For the Asian region, a study in China found the prevalence of OSA at the age of 30-60 years is about 4.1% in men and 2.1% in women.[5] The causes of OSA include various factors related to the anatomy of the upper airway, such as narrow airway space, mandibular retrognathia, increased tongue volume, and enlarged palatine or adenoids.[1,2,4] OSA presents with signs and symptoms such as snoring during sleep, excess daytime drowsiness, and decreased intrathoracic pressure.[1,4] Predisposing factors for OSA in adults are obesity, age, sex, smoking, craniofacial abnormalities, and morphological abnormalities of the upper respiratory tract.[2,6,7] If OSA is not diagnosed promptly, the patient's condition can worsen due to OSA complications such as hypertension, cardiovascular disease, and decreased cognitive abilities that can lead to traffic accidents.[8,9] However, due to the lack of awareness among general public and health professionals, early detection and diagnosis of OSA is very important to prevent more serious complications.

Gold standard in diagnosing OSA is polysomnography (PSG). This examination involves an ENT specialist in assessing the severity of OSA.[1,3,10] However, polysomnography is relatively time consuming, complicated and expensive. In addition, polysomnography does not show a specific location of airway obstruction, therefore other diagnostic modalities and imaging technologies are needed.[1,3,11] Many advanced modalities have been reported to be able to assess the anatomy of orofacial structures in OSA patients including computed tomography, and magnetic resonance imaging.[11] Lateral cephalometry radiograph has been widely used in orthodontic to provide information regarding the sagittal and vertical relationships of craniofacial structures, soft tissue profiles, teeth, pharynx, and cervical vertebrae.[9] The relationship between these structures is checked by linear or angular measurements, which is important for finding the point of obstruction in OSA patients.[12] Lateral cephalometric radiography is a radiograph that is widely used to analyze bone and soft tissue characteristics of OSA patients. In evaluating

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pharyngeal obstruction in OSA patients, lateral cephalometry is still used today. Some researchers have found dentofacial morphological aberrations in patients with respiratory disorders, namely airway narrowing seen in conventional lateral cephalometry.[13] Cephalometric radiographs are mainly used to evaluate the hard and soft tissues of the head, are relatively inexpensive, easy to perform, and easy to obtain[3,11, 14]

Compared to the gold standard examination, lateral cephalometry can improve early detection and prediction of OSA by dentists. Therefore, the researcher wanted to investigate the changes in anatomic factors in OSA through means cephalometric radiography, which includes the relationship of position and size, which were reported in the literature. It is hoped that the results of this literature review can enrich the insight of dentists in predicting the possibility of OSA, which can be associated with various abnormalities of jaw growth and development.

REVIEW

A literature review using articles databases available on the PubMed and Scopus databases. The search keywords used were "obstructive sleep apnea" and "cephalometry". The inclusion criteria were discussing Obstructive Sleep Apnea (OSA) in adults aged 18-80 years with lateral cephalometry that had been indexed by Scopus and labeled Q1, Q2, and Q3. Selected article searches are free full-text articles written in English published during the period 2011-2021, and are original articles from Dental Journals on the subject of dentistry. From this search, 8 articles were obtained according to the age range criteria. Two articles were omitted because they included a literature review, 1 article did not show the mean and standard deviation values, and 1 article used different parameters. Thus, 4 selected articles were obtained.

Table 1. Parameters of OSA analysis in general[15,16]

PARAMETER	RANGE	SCALE
Anthropometry and upper airway anatomy		
IMT,Kg/m^2	17.2-42.2	Body mass index (m^2)
Nasal obstruction	0-2	Symptoms of nasal obstruction: (0, no nasal obstruction; 1, nasal obstruction during the day or night; 2, nasal obstruction during the day and night)
Updated Friedman tongue position (uFTp)	1-3.5	The anatomical relationship between the tongue and the tonsils, uvula, soft palate, and
Tonsil size grading	0-4.0	0, surgically removed tonsils; 1, the tonsils are hidden in the pillars; 2, the tonsils extend to the pillars; 3, the tonsils are outside the pillars but not to the midline; and 4, tonsils extending to the midline
Uvular length (cm)	0.3-3.0	The length of the uvula was measured by using a small straight caliper from the base to the distal tip of the uvula in the midline, with the subject sitting in an upright position with the mouth open and the tongue inside.
Neck circumference (cm)	29-49.8	Neck circumference (cm) was measured just below the laryngeal prominence with the head positioned in the Frankfort horizontal plane
Waist circumference (cm)	62-128.5	Waist circumference (cm) is measured midway between the last rib and the crest of the crista
Hip circumference (cm)	82.5-129	Hip circumference (cm) measured as high as trochanter mayo
Hyoid-mental distance (cm)	2.5-7.8	The hyoid-mental distance (HMD; cm) from the hyoid bone to the mental protrusion was measured at the end of the expiratory phase and without swallowing.
Thyroid-mental distance (cm)	3.2-8.25	Mental-thyroid distance (TMD; cm) from the thyroid pharynx to the mental prominence

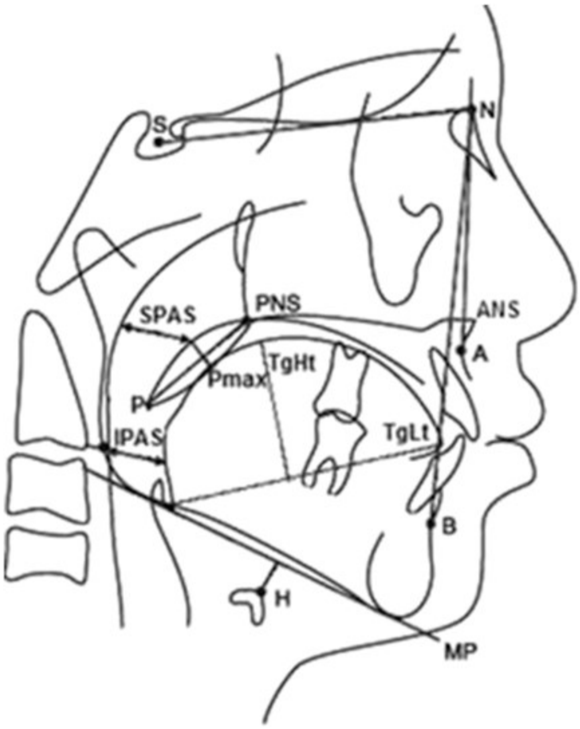

Figure 1. Graphical representation of landmarks, reference lines, and cephalometric parameters

Table 2. Common parameters in cephalometry[17–20]

VARIABLE	DESCRIPTION	NORMAL VALUE
CRANIOFACIAL STRUCTURES		
SNA	Angle formed by the sella-nasion line and line N-point A	82°
SNB	Angle formed by the sella-nasion line and line N-point B	80°
ANB	Differences between the SNA and SNB angles	2°
SN.GoMp	Angle formed by the sella-nasion line and mandibular plane	36°
1.NA	Angle of inclination of the upper incisor in relation to the NA line	22°
SOFT PALATE		
PNS-P	Linear distance between the PNS and the tip of the soft palate	47 mm
PmAX	Soft palate thickness; maximum diameter of the soft palate perpendicular to the PNS–P	
SPAS	upper posterior pharyngeal space	17-20 mm
IPAS	lower posterior pharyngeal space	11-15 mm
TGL	Tongue length: the distance between the base of the epiglottis and the tip of the tongue	78 mm
TGH	maximum height of the tongue	31 mm
MP-H	Linear distance between H, the most anterosuperior point of the hyoid bone, and the mandibular plane measured perpendicularly to the latter	15 mm
C3-H	Linear distance between the 3rd vertebrate bone and the hyoid	35 mm

Table 3. Characteristics of selected articles

AUTHOR	YEAR	TYPE OF STUDY	SAMPLE	TITLE	SCOPUS INDEX
Albajalan Osama B	2011	Observational study	Fifty Malays (32 males and 18 females) aged 18–65 years divided into two equal groups 25 (17 males and 8 females) with OSA and a control group 25 subjects (15 males and 10 females).	Craniofacial morphology of Malay patients with obstructive sleep apnea	Q1
Patricia Superbi Lemos Maschtakow et al	2013	Comparative study	55 lateral cephalograms (age 20-70 years) consisting of 29 for the control group of adult individuals without clinical characteristics of OSAHS and 26 apneic adults	Cephalometric analysis for the diagnosis of sleep apnea: A comparative study between reference values and measurements obtained for Brazilian subjects	Q2
Finn Geoghegan et al	2015	Cohort study	45 consecutively referred Chinese adult (age 27-79 years) patients with OSA	An evaluation of two different mandibular advancement devices on craniofacial characteristics and upper airway dimensions of Chinese adult obstructive sleep apnea patients	Q1
Ahmet Yalcin Gungor et al	2019	Observational study	32 patients: included 16 OSA patients (11 men and 5 women; mean age, 51.5 ± 11.01 years) and 16 healthy subjects (10 men and 6 women; mean age, 48.06 ± 9.74 years	Cephalometric comparison of obstructive sleep apnea patients and healthy controls	Q2

Table 4. Comparison of parameter calculations of OSA patients with lateral cephalometry in 4 journals

PARAMETER	ALBAJALAN (N=50) (MEAN)	PATRICIA SUPERBI (N=55) L	P	FINN GEOGHEGAN (N=45) (MEAN ±SD)	AHMET YALCIN GUNGOR (N=32)
SN	69.00	74.8 ± 3.3	68.4 ± 3.93	72.9 ± 4.3	
SNA (°) ±SD	86.34			81.5 ± 3.7	80,93 ± 3,84
SNB (°) ±SD	84.44			77.3 ± 3.2	79,55 ± 4,59
ANB (°) ±SD	3.16			4.2 ± 2.4	1,39 3 ± 41
ANS-PNS		56.9 ± 5.1	48.8 ± 4.64		
SN-GoMp (°) ±SD				35.9 ± 6.4	32,66 ± 7,36
PNS-P (mm) ±SD		43.3 ± 4.5	41.14 ± 3.14	41.9 ± 4.9	42,71 ± 5,14
Pmax (mm) ±SD				11.4 ± 2.8	9,84 ± 2,02
Overjet (mm) ±SD				4.0 ± 2.3	
Overbite (mm) ±SD				2.5 ± 1.7	
TgLt (mm)±SD	91,48			85.8 ± 8.9	
TgHt (mm) ±SD				38.6 ± 7.0	
MP-H (mm) ±SD	39.74	26 ± 6.5	23.88 ± 7.26	21.8 ± 5.5	25,87 ± 7,33

(Cont.) Table 4. Comparison of parameter calculations of OSA patients with lateral cephalometry in 4 journals

PARAMETER	ALBAJALAN (N=50) (MEAN)	PATRICIA SUPERBI (N=55) L	P	FINN GEOGHEGAN (N=45) (MEAN ±SD)	AHMET YALCIN GUNGOR (N=32)
SPAS (mm) ±SD	8.18 (mean)	14.4 ± 3.5	16.75 ± 3.78	27.4 ± 3.3	10,67 ± 3,27
IPAS (mm) ±SD	11.62 (mean)	15.1 ± 2.8	12.01 ± 2.74	8.6 ± 2.6	7,12 ± 2,81
B-Go/BI		12.1 ± 3.2	7.12 ± 1.57		
C3-H(mm) ±SD		43.4 ± 5.1	41.68 ± 7.09		
C3'-H'		6.1 ± 2	6.08 ± 2.35		
Conclusion	In this study there was no significant difference in maxillary and mandibular discrepancies in both OSA patients and controls. The changes that occurred in this study were the size of the soft palate and tongue, which was longer, the position of the hyoid which was inferior to the mandibular plane occupied more space in the oropharynx, causing narrowing of the airway.	In this study, the anatomical factors of PNS-P decreased in OSA patients compared to controls. Nasopharyngeal narrowing is associated with adenoid hypertrophy in OSA patients and a more anterior hyoid bone is associated with OSA severity. .	In this study, the anatomical factors of PNS-P decreased in OSA patients compared to controls. Nasopharyngeal narrowing is associated with adenoid hypertrophy in OSA patients and a more anterior hyoid bone is associated with OSA severity. .	Significant improvements were found in SPAS, soft palate length and hyoid position in relation to the mandible as well as decreased PNS-P distance. There was no significant difference in the maxilla but in the mandible, there was a decrease in the SNB angle, which caused retrognathia and was associated with the distance of the hyoid bone which has a role in regulating the position of the pharyngeal airway.	There was no significant difference between the groups in the SNA SNB and SN-GoMp angles. The greater distance of the hyoid with the mandible in OSA patients causes upper airway collapse.

DISCUSSION

OSA is diagnosed through history taking that must inquire information regarding sleep patterns, alongside physical examination, radiographic examination and special test. Sleep pattern analysis is carried out by assessing sleep habits using the Epworth Sleepiness Scale (ESS) questionnaire, special physical examination for OSA using Mueller's Maneuver, Drug Induced Sleep Endoscopy (DISE), and polysomnography (PSG) as the gold standard for the diagnosis of OSA through overnight sleep examinations. Anatomical factors that play a role in OSA patients can be evaluated by cephalometric radiographic examination.[15,21]

Determination of upper airway abnormalities classification during evaluation of OSA subjects requires general analysis from physicians (Table 1). During physical examination, BMI and neck circumference were measured and evidence of septal deviation or nasal polyps were also observed, size of the tongue, palate and uvula were also taken into consideration. Friedman et al. presented the Mallampati degree, which was formulated to assess the relationship between modified tongue and palate regarding tongue position by examining the relative position between the palate, uvula, and base of the tongue without protruding the tongue. This modification provides a more natural and physiological tongue position that approximates hypopharyngeal obstruction and is similar to that achieved during sleep.[15,16]

Lateral cephalometric radiographic examination is an extra-oral follow-up examination in dentistry that is often carried out, especially in orthodontic treatment. This radiograph is also very important for analyzing growth, diagnosis of OSA, treatment planning and evaluation of treatment outcomes. Lateral cephalometric radiographs can be used to analyze the bone and soft tissue characteristics of OSA patients. When evaluating pharyngeal obstruction in OSA patients, lateral cephalometric radiographs were performed with the patient sitting in an upright position and head against the wall, using a cephalostat, along with a horizontal Frankfort orientation. The irradiation conditions are 100Kv and 50mA, and the shooting time is 0.4-0.6 seconds with a distance of 180 cm from the X-ray tube to the cassette.[3,20]

Evaluation of the upper airway can be done with a lateral sagittal dimension in cephalometric radiographic examination. This literature compares the cephalometric variables from 4 publications[1,4,9,22] which considered the variables closely related to OSA. The variables used were craniofacial skeleton parameters: SN, SNA, SNB, ANB, ANS-PNS, and SN-GoMp angles; oropharyngeal region parameters: PNS-P, Pmax, SPAS, IPAS, Hyoid bone, and tongue area. Albajalan used SN, SNA, SNB, ANB, MP-H, SPAS, IPAS. Patricia used SN, ANS-PNS, MP-H, SPAS, IPAS, B-Go/BI, C3-H, C3'-H'. Geoghegan used almost all parameters except ANS-PNS, B-Go/BI, C3-H, C3'-H', and Gungor used SNA, SNB, ANB, SN-GoMp, Pmax, MP-H, SPAS, IPAS

Several parameters were included in the craniofacial aspect analysis. Smaller SNA and SNB angles are often cited as one of the severity factors for OSA.[3] In this literature review, there are 3 articles that used SNA, SNB, ANB, and Go-SnMp parameters. From their research results, only Finn geoghegan et al obtained significant differences in SNB parameters. According to Chakravarty, there is strong evidence of changes in maxillary and mandibular size in OSA patients showing a decrease in the SNB angle, a decrease in mandibular length, and clockwise rotation of the mandible in OSA subjects. This anatomic difference places the entire cranial base closer to the spine and contributes to the reduced airway space in OSA.[2,9] According to

Table 5. Observations and perspectives

AUTHOR	YEAR	CRITERIA	SAMPEL	CONCLUSION
Albajalan osama et al	2011		Fifty Malays (32 males and 18 females) aged 18–65 years divided into two equal groups 25 (17 males and 8 females) with OSA and a control group 25 subjects (15 males and 10 females).	OSA subjects had a significant increase in body mass index (BMI) and neck circumference than the control group. The soft palate and tongue were longer and thicker in OSA patients. In addition, upper, middle, and lower posterior airway spaces were narrower, the hyoid bone was more inferior and posterior, and the cranial base flexure angle was significantly acute when compared with the control group
Patricia Superbi Lemos Maschtakow et al	2013	Original article	55 lateral cephalograms consisting (age 20-70 years) of 29 for the control group of adult individuals without clinical characteristics of OSAHS and 26 apneic adults	There were no significant differences between values obtained from control group and standard values. On the group of OSAHS patients it was observed a decrease on the dimensions of upper airways and an increase on the soft palate length
Finn Geoghegan et al	2015	Original article	45 consecutively referred Chinese adult (age 27-79 years) patients with OSA	The Apnea-Hypoxia Index was highly significantly reduced with the monoblock (P, .001) and significantly reduced with the twin block (P, .01). The monoblock demonstrated a superior result than the twin block (P, .05). A significant reduction was found in the distances between the hyoid bone to retrognathia (monoblock, P, .01; twin block, P, .001) as well as the distance between the hyoid bone and mandibular plane angle (P, .001). Furthermore, soft palate length increased significantly (P, .05) with both MADs. However, the changes did not differ in favor of either MAD.
Ahmet Yalcin Gungor et al	2019	Observational study	32 patients: included 16 OSA patients (11 men and 5 women; mean age, 51.5 ± 11.01 years) and 16 healthy subjects (10 men and 6 women; mean age, 48.06 ± 9.74 years	Midface length was significantly shorter and upper lip E-plane length was significantly longer in the OSA group than in the controls (P<.05). SNA, SNB, and mandibular plane angles (GoGn-SN), anterior and posterior facial heights, and posteroanterior face height ratio were similar in both groups. Maxillary length was slightly longer in the OSA group, whereas the mandibular length showed a slight increase in the control group (P<.05). The axial inclination of the lower incisor to its respective plane was normal, whereas the upper incisor was significantly protrusive (P<.05) in the OSA group. Distance between the hyoid and mandible was significantly greater in the OSA group than in the controls, indicating that the hyoid bone was positioned more downward in the OSA group (P<.05)

Kimm et al (2020) skeletal restriction is an important risk factor that predisposes to upper airway collapse mostly in combination with other phenotypic causes.[23] However, craniofacial phenotypic characteristics of OSA may differ between race and ethnicity.[2] In this literature review the value of SNAs were very similar in some investigators which meant that the relationship of maxilla to the cranial base was normal. There is a significant difference in the value of the Sn-GoMp angle of OSA patients between the cranial base and the mandibular plane, which when decreased indicates that the mandible is more posterior to the cranial base (retrognathic). According to Tepedino et al (2020) decreased mandibular length can affect the severity of OSA and is highly correlated to sagittal length with respect to the base of the cranium[6]. Thus it can be concluded that a retrusive mandible can affect the severity of OSA.

Determination of the hyoid bone is important because of its relationship to tongue mass. Several studies have described changes in the mass of the tongue and hyoid bone that are inferior in OSA patients than in controls. This literature review confirms this. The MP-H parameter resulted in significant heterogeneity between studies. The study conducted by Silva et al (2014) showed that patients with moderate and severe OSA had significantly increased MP-H values than patients with mild OSA.[14] According to Albajalan et al. (2011) hyoid bone changes were inferior in OSA patients compared to the control group because the hyoid bone serves as a support for the tongue muscles and the infero-posterior displacement will pull the tongue muscles down and back, resulting in a larger tongue mass in OSA patients.[22] Several investigators reported that the MP-H parameter was acceptable for the diagnosis of OSA. The same finding were shown by Chakravarty et al (2017), which demonstrated that the superior/inferior relationship of the hyoid bone is one of the diagnostic indicators of OSA and its severity and this study also showed evidence of inferior hyoid bone changes in OSA patients related to the mandibular plane and sella tursica. Inferior displacement of the hyoid bone can lead to pharyngeal collapse.[2] In order to reduce measurement error, a lateral cephalometric radiograph is taken when the patient exhales deeply because in this condition the hyoid bone is fixed. Several literatures have stated the distance between the 3rd and 4th vertebrae to the hyoid bone is increased in OSA patients. From the analysis described above, it can be concluded that the inferior hyoid bone can be used as an indicator of OSA in patients.[3]

This literature review is in line with the statement that the oropharyngeal dimensions between the soft palate, dorsum of the tongue and pharyngeal wall in OSA subjects are almost all reduced except according to Geogherhan et al and Patricia Superbi et al who stated that in male patients it was increased. Chiang et al (2012) also found an increase in the size of airway space in male patients with an elliptical shape.[24] Upper airway obstruction is very important in the pathogenesis of OSA. The pharyngeal airway is a highly dynamic structure and is influenced by skeletal and soft tissues. The decrease in pharyngeal airway space may be due to changes in the size of other structures namely the tongue, palate, maxilla and mandible.[2,25] A similar study according to Chakravarty, Armalaite, Gungor, Sutherland, Stipa C, Nishanth and Silva et al. showed a significant increase in upper airway length (PNS-P) and decrease in posterior airway length (SPAS) which showed that hyoid bone is lower.[2–4,7,11,14,26] The literature review supports the assertion that the oropharyngeal dimension between the palate, dorsum of the tongue and pharyngeal wall in OSA subjects are increased.

Some investigators have suggested that upper airway obstruction is associated with anatomic variations in head posture and an increase in the cranio-cervical angle in subjects with OSA, which was formed to increase airway dimensions. Vidovic et al (2013) found that the mean cranio-cervical angulation was much greater in the OSA sample than the control group, which could be interpreted as a physiological adaptation that elevates the base of the tongue and soft palate from the posterior pharyngeal wall to relieve the obstructive condition.[3,27] These findings can explain the differences in narrowing of the oropharyngeal width on the soft palate and dorsum of the tongue found in several studies.[1,2,7,26] According to Juste et al (2016) the cephalometric data analyzed support the concept of soft tissue abnormalities in OSA patients and the SPAS width can be a prognostic parameter for OSA diagnosis. Although this concept still needs further research.[3]

Several researchers reported that the size of the soft palate has increased in OSA patients.[2,3,11,22,28,29] This is in line with research conducted by Laxmi et al (2015) which demonstrated that changes in patients position can affect the length of the soft palate associated with OSA, where supine position will cause the soft palate to move more anteriorly, increase in thickness and push the tongue mass superiorly. In line with research conducted by Armalaite et al (2015)[3], which reported that in the supine position, the width of the uvula increased, the pharynx is widened, and the hyoid bone is more anterior. An increase in the thickness and length of the soft palate has also been reported to occur with age, and in OSA patients there is an increase in tongue area and length in OSA patients showed a more posteriorly positioned tongue mass.[2] in line with the research conducted by Amajohal et al which also described that the tongue's length and area increase significantly in all OSA patients causing the tongue to be in a more posterior position.[28] The results of the study by Albajalan et al. demonstrated a significantly longer tongue length and thickness in OSA patients, which occupies more space in the oropharynx, thus resulting in airway narrowing. In addition, in the supine position, the tongue falls back and blocks the hypopharyngeal space. Thus, the larger the size of the tongue, the greater the possibility of airway obstruction.[22] From this description it can be concluded that the soft palate and a longer tongue can be used as indicators of OSA patients.

CONCLUSION

Based on this review, we can conclude that dentists can perform early detection of OSA through lateral cephalometric radiograph which originally is the initial screening tools by paying attention to the patient's position at the time of exposure, the irradiation conditions (kV, ma and sec) and the patient's position in the diagnosis of OSA in relation to soft and hard tissues to be evaluated. Certain craniofacial morphological variables can be relied upon as predictors of OSA occurrence. Mandibular retrusion and increased tongue dimensions will cause pharyngeal airway obstruction. An increase in MP-H, Pns-P and a decrease in SPAS, IPAS can be suspected as an OSA condition, therefore these parameters can be used as a simple additional method by dentists and ENT specialists before a polysomnography (PSG) examination is performed. In an effort to detect OSA conditions early, these parameters need to be properly memorized by dentists and can also be used as a simple additional method by doctors. Further research on OSA patients in the Indonesian population using these parameters can be suggested.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article.

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