Access this article online
Quick Response Code:
Website:
www.jorthodsci.org
DOI:
10.4103/jos.jos_80_25

Three-dimensional evaluation of anterior parameters and palatal height index in obstructive sleep apnea adults using cone beam computed tomography: A Case control study

Mélanie Chahwan, Joseph Bouserhal[1], Alain Tauk[2,3], Nabil Ghosn[3], Terry El Wak[4] and Amine El Zoghbi

Department of Prosthodontics and Occlusion, School of Dental Medicine, Saint Joseph University of Beirut, Beirut, Lebanon, [1]Department of Orthodontics and Dentofacial Orthopedics, Goldman School of Dental Medicine, Boston University, Boston, United States, [2]Department of Orthodontics, School of Dental Medicine, Saint Joseph University of Beirut, Beirut, Lebanon, [3]Department of Digital Dentistry, AI and Evolving Technologies, Saint Joseph University of Beirut, Beirut, Lebanon, [4]Private Practice, Dubai, United Arab Emirates

Address for correspondence:
Dr. Terry El Wak, Private Practice, Dubai, United Arab Emirates. E-mail: terry.wak@hotmail.com

Submitted: 02-Jun-2025
Revised: 03-Dec-2025
Accepted: 09-Feb-2026
Published: 27-May-2026

Abstract

PURPOSE: The aim of the study was to compare the anterior parameters and the palatal height index (PHI) in obstructive sleep apnea (OSA) patients and control subjects, using cone-beam computed tomography (CBCT).

MATERIALS AND METHODS: The CBCT data of 30 male OSA patient diagnosed with polysomnography and 30 male control subjects with no sleeping disorders were analyzed using the software 3D Slicer. The head position during the scan was similar in both groups. The anterior parameters (overjet and overbite) and the PHI were calculated. Independent samples T-test was used to identify statistically significant differences between the means of two independent groups. Chi-square test was used to assess relationship between categorical variables. A P value of less than 0.05 was considered statistically significant.

RESULTS: The mean value of PHI was lower in the OSA group ($P = 0.010$). No statistically significant difference between the means of overbite and overjet was found between the two groups.

CONCLUSION: The anterior parameters did not show significant differences between the groups. However, the OSA group have a significantly lower mean PHI than the control group.

Keywords:

Cone beam computed tomography, overbite, overjet, palatal height index, palate, sleep apnea

Introduction

Obstructive sleep apnea (OSA) is a breathing disorder due to the obstruction of the upper airway during sleep.[1] Disrupted sleep and daytime sleepiness is not the only symptom reported, but a negative quality of life is associated with this disease.[2] The etiology is not fully understood, it's a combination of anatomical and pathophysiological factors.[3] The gold standard for determining the presence and severity of OSA is polysomnography. However, it requires an overnight evaluation.[2,4] Nowadays, cone beam computed tomography (CBCT) is being used as a screening tool for patient with OSA due to its non-invasive capacity in identifying obstructions, constrictions and anatomic abnormalities that might increase the risk of sleep apnea.[5]

Management of OSA could be[1] surgical: tracheostomy, uvulopalatopharyngoplasty, uvulopalatoplasty, rapid maxillary expansion, and maxillomandibular

How to cite this article: Chahwan M, Bouserhal J, Tauk A, Ghosn N, El Wak T, El Zoghbi A. Three-dimensional evaluation of anterior parameters and palatal height index in obstructive sleep apnea adults using cone beam computed tomography: A Case control study. J Orthodont Sci 2026;15:13.

advancement,[2] nonsurgical: continuous positive airway pressure (CPAP) Continuous Positive Airway Pressure, oral appliances such as tongue-retaining devices and mandibular advancing devices, and[3] behavioral modification as weight loss.[6]

Various studies have used CBCT to analyze the upper airway anatomy, to assess anatomical changes after surgical or oral appliances and to evaluate craniofacial abnormalities, in patient with mild to severe OSA, healthy and obese patients. Dental arch form morphology and interdental width were also compared between OSA patients and healthy patients on dental cast.[7-11]

Other studies have evaluated tooth position and overjet after the usage of a mandibular protruding device (MPD). A mandibular protruding device is used to treat mild to moderate OSA, but long-term usage of this device may cause a proclination of the lower incisors and a retroclination of the upper incisors. Patients suffering from an overjet could benefit from this device but not subjects suffering from a class III.[10] Moreover, some studies reported the development of an infra-occlusion after long term treatment with a MPD.[12]

The treatment outcome of oral appliances has been assessed in many studies,[12-15] but the anterior parameters have not yet been compared on a CBCT between healthy patients and patients suffering from OSA. A better understanding of the anterior parameters would be important not only to diagnose patients with a higher risk of developing OSA, but for measuring the effectiveness of the available treatment.

The 3D morphology of the palate was studied in the Korean population and showed no statistical differences between patient with and without OSA in the most palatal measurement however the palates of OSA patients were higher in the posterior part, and narrower in the anterior-superior part than those of the control group.[16] The findings of this study were not in accordance with the results of others studies that showed a correlation between the constriction of the maxilla and OSA.[17-19]

The palatal height index (PHI) is used to determine if the palate is too shallow or the maxilla is too constricted[5] and the formula is a percentage. If this dimension is greater than 42%, the maxillary arch is constricted. If the dimension is significantly less than 42%, the palate is shallow. The PHI has not yet been studied in patients suffering from OSA. Comparing this index between patient with and without OSA would help us understand better the anatomy of high-risk patients.

The aim of this study was to compare anterior parameters (overbite and overjet) and the PHI between patients with sleep apnea and patients without respiratory disorders. The null hypothesis was that there are no differences in the anterior parameters and the PHI between patients with OSA and subjects without respiratory disorders.

Materials and Methods

Study samples

The samples used were taken from the study by Mouhanna-Fattal *et al*.[7] It consists of 60 adult patient, all male, divided equally into two groups:

- The OSA group consists of 30 patients suffering from sleep apnea and was chosen from the Otolaryngology and Pulmonary Department of hospitals in Beirut, Lebanon. The apnoea-hypopnea index (AHI = number of apneas and hypopneas) was used to diagnose OSA following a nocturnal polysomnography. Moreover, patients from the OSA group completed the Berlin questionnaire and the Epworth sleepiness scale. From the 30 patients, 13 have shown daytime sleepiness on the Epworth sleepiness scale and 23 scored positively on the Berlin questionnaire. Inclusion criteria were: presence of at least 20 healthy or replaced teeth, presence of the first maxillary molars, presence of the anterior teeth and a stable occlusion. Patients with an history of upper airway surgery or a contraindication for the scan (CBCT) were excluded.
- The control group consisted of 30 healthy adults with no history of sleep disorders. To avoid an unnecessary exposure to X-rays, the control group was chosen from patients, who had undergone a CBCT examination of their head for dental or orthodontic purposes from a dental imaging center in Ashrafieh, Lebanon. Inclusion criteria were a negative score in sleeping questionnaire, presence of the first maxillary molars and the anterior teeth with no history of upper airway surgery or sleep apnea treatment.

To reduce the risk of bias. The control and the OSA group were matched as close as possible in the terms of body mass index and age. The mean age of the OSA group was 49 years and 4 months, while the mean age of the control group was 44 years and 4 months. Concerning the body mass index, the OSA group mean value was 32.83 and the non-OSA group mean value was 28.02.

Data analysis

All the CBCT-scans, in this retrospective study, were performed with a Kodak 9500 Cone Beam 3D System (Care stream Health, Inc., Rochester, New York, USA). The patients were in their natural head position and the occlusion in maximal intercuspal position during CBCT acquisition. The numerical data was saved in DICOM (Digital Imaging for Communication in Medicine) format. Patients informed consent has been provided. The Saint Joseph University of Beirut, Lebanon ethical committee approved the study protocol (USJ-2022-200).

The software 3D slicer 4.11.20210226[20] was used to analyze the anterior parameters and the PHI.

First, the occlusal plane was defined by the incisal and occlusal surfaces of the teeth and was considered as a reference plane to measure the overbite and the overjet [Figure 1]. The overbite was measured on a sagittal view at the incisal edge of the maxillary central incisor with the most vertical overlap [Figure 2a]. The distance calculated was the projection of the incisal maxillary edge to the labial surface of the opposite mandibular central incisor (parallel to the occlusal plane) to the incisal edge of the same tooth [Figure 2b]. The overjet was measured on a sagittal view from the most prominent point of the maxillary central incisors to the mandibular central incisor parallel to the occlusal plane [Figure 3].

The palatal height index is measured on a frontal view at the level of the first molars [Figure 4]. The formula is a percentage:

$$\text{Palatal height index} = \frac{\textit{palatal height}}{\textit{posterior arch width}} \times 100$$

The posterior arch width is the distance between the maxillary first molars. The central groove or the deepest part of the occlusal surface is used as reference point to measure this distance due to its reliability [Figure 4a]. The palatal height measurement is the perpendicular line from the midline of the palate at the deepest point to the posterior arch width line [Figure 4b].

Statistical analysis

A descriptive statistical analysis was first carried out: Quantitative variables are presented as means and standard deviations, and the qualitative variables are presented by their frequencies and their percentages.

Bivariate analysis was performed to assess any statistically significant differences between anterior parameters and PHI between the two groups (with and without respiratory disorder); and potential relationships between palate type and the presence of a respiratory disorder. Independent samples T-test was used to identify statistically significant differences between the means of two independent groups. Chi-square test was used to assess relationship between categorical variables. Statistical analysis was performed with (IBM) International Business Machines (SPSS) Statistical Package for the Social Sciences Statistics 25. A P value of less than 0.05 was considered statistically significant.

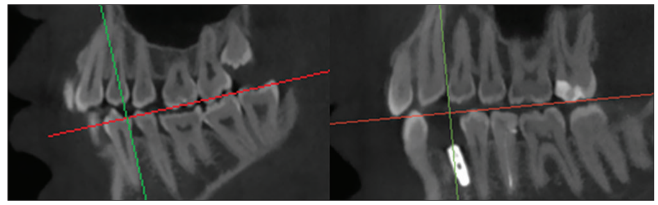

Figure 1: Occlusal plane

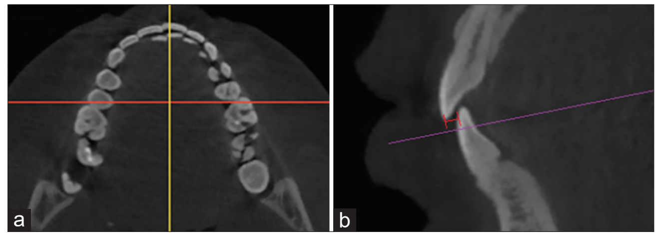

Figure 2: (a) Maxillary central incisor with the most vertical overlap. (b) Overjet measurement, occlusal planemeasurement, occlusal plane

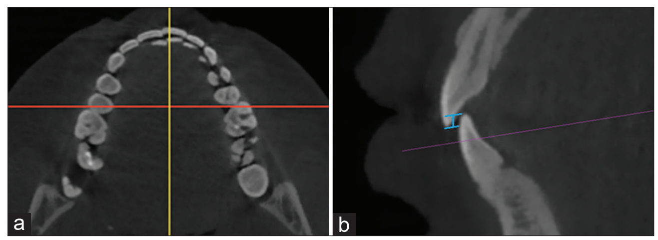

Figure 3: (a) Maxillary central incisor with the most vertical overlap. (b) Overbite measurement, occlusal planemeasurement, occlusal plane

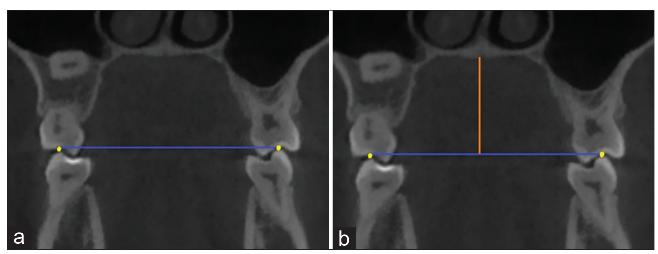

Figure 4: Palatal height index. (a) Posterior arch width, central groove, and (b) palatal heightpalatal height

Results

The null hypothesis was rejected for the overjet, overbite, and palatal width.

The bivariate analyses [Table 1] showed:

- No statistically significant difference between the means of overbite and overjet of subjects in the two groups, with respectively, ($P = 0.157$) and ($P = 0.474$).
- A statistically significant difference was observed between the mean palatal height of the two groups, those with a respiratory disorder having a significantly lower mean height than those without a respiratory disorder ($P = 0.037$).
- A statistically significant difference was observed between the mean PHI of the two groups, those

Table 1: Anterior parameters and palatal height index in the group with OSA and the control group (*n*=60)

	OSA group		Control group		Mean difference	*P*
	Mean	SD	Mean	SD		
Overbite	1.913	1.643	1.39	1.12	–0.52	0.157
Overjet	2.53	1.80	2.17	2.09	–0.36	0.474
Width	48.18	4.37	46.68	5.04	1.51	0.221
Height	21.57	2.49	22.89	2.25	1.31	0.037
PHI	45.00	5.72	49.60	7.49	4.59	0.010

with a respiratory disorder having a significantly lower mean PHI than those without a respiratory disorder ($P = 0.010$).

- The Chi-square test showed no statistically significant relationship between the type of palate and the presence of respiratory disorders ($P = 0.181$).

Discussion

This study used CBCT to compare the overbite, overjet, and the PHI in OSA patients and control subjects.

The limitation of this study would be the standing position of the patients during the CBCT acquisition. However, it was unnecessary to expose the control group for extra radiation for ethical reasons. Therefore, both groups had their CBCT in the upright position. The study of Camacho *et al*.[21] compared the total volume and the cross-sectional area parameters in obstructive sleep apnea patient in supine versus upright position. They noted that when OSA subjects were in a supine position, the airway was smaller than when they were in an upright position. The difference in upper airway volume between the upright and supine positions was significant. This could be explained by the effect of gravity on the palate and a displacement of the tongue base backwardly. Although this study considered a small sample size of five patients, which may constitute a limitation.

The systematic review and meta-analysis that analyzed 29 studies and described the procedures for upper airway evaluation showed that, regardless of the posture during the scan, the upper airway volume and the anteroposterior dimension was also smaller in patients with OSA in comparison to the control group that means that the position during the scan would not affect any measurement comparison.[22]

Some craniofacial deformities and anatomical factors have been linked with OSA. Malocclusion is a type of craniofacial anomaly that is known to trigger mouth breathing.[23] Mouth breathing can result in the tongue shifting backwards that can reduce the upper airway volume leading to OSA.[24] Moreover, a severe overjet can be a contributing factor to mouth breathing because it is more difficult to close the lips.[25]

In order to investigate the influence of malocclusion on the incidence of OSA, Miyao *et al*.[12] evaluated the malocclusion in 97 Japanese male patients with OSAS. Overbite and overjet were calculated on the cephalogram and the dental cast. The findings of dental cast analysis showed that patients with OSA had a higher prevalence of deep overbite and severe overjet. The results were explained by the fact that certain maxillofacial features can influence breathing. Teeth location and craniofacial structures growth can shift breathing from nasal to mouth breathing that can easily cause a backward position of the tongue leading to obstructive events during sleep. While sleeping the muscles that usually keep the upper air way open seem to relax.[23,26] However, the finding of this study were not in accordance with our results. In fact, the statistical analysis did not show any significant difference between the means of overbite and overjet of subjects with or without respiratory disorders.

The study of Yu *et al*.,[16] evaluating the morphology of the hard palate in three dimensions (3D) between Korean adults with and without OSA, showed significant differences in the width of the hard palate in the anterior-superior part, the height of the posterior part at the end and the width of nasal cavity. The palate at the lower posterior and anterior-superior parts was narrower. Patients with OSA had narrower nasal cavities compared to the control group. The posterior part of the palate was higher in OSA patients. This finding was in accordance with our study, where significant differences were found between the height of the palate in the posterior region at the level of the first premolar. These findings also agreed with those of a Japanese study,[18] that stated that the constriction of the dental arch in the maxilla could be linked to the occurrence of OSA, but it was not a common feature in Japanese OSA patients. This could be explained by the fact that maxillary constriction is related to a lower position of the tongue that can lead to narrowing of the airway in the retroglossal area and cause obstructive events.[27]

Kecik[17] assessed if there is any correlation between the morphology of the palate and the upper airway. Their results showed a decrease in the intermolar width in the OSA group, and were consistent with those of Bresolin *et al*.,[28] Harari *et al*.,[29] and Berwig *et al*.[19] This could be explained by the constriction of the maxilla in OSA patients as a compensating mechanism that keeps the occlusion while the mandible moves backwards. These results were not in accordance with the results of our study where the palatal width calculated at the level of the first molars did not differ between the control and OSA group. However, the width alone is not an indicator of construction and the height should also be taken into consideration.[30]

Conclusion

Within the limitations of our study, we may conclude that the anterior parameters of patients with OSA is not different than those with no sleeping disorders. The palatal height is significantly lower in the OSA group that can indicate an upper airway obstruction in the OSA group. The CBCT could be an easy alternative to evaluate anatomical and dental changes in high-risk patients, but more research is needed to evaluate CBCT as a tool for assessing OSA patients.

Study data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Authors contributions

MC: Conceptualization, methodology, writing original draft. JB: Resources, supervision. AT and TEW: Review, editing, validation. NG: Software, data curation. AEZ: Project administration.

Financial support and sponsorship

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

All authors state that they have no conflicts of interest.

References

1. Jordan AS, McSharry DG, Malhotra A. Adult obstructive sleep apnea. Lancet 2014;383:736-47.
2. Veasey SC, Rosen IM. Obstructive sleep apnea in adults. N Engl J Med 2019;380:1442-9.
3. Lee JJ, Sundar KM. Evaluation and management of adults with obstructive sleep apnea syndrome. Lung 2021;199:87-101.
4. Chiu HY, Chen PY, Chuang LP, Chen NH, Tu YK, Hsieh YJ, *et al*. Diagnostic accuracy of the Berlin questionnaire, STOP-BANG, STOP, and Epworth sleepiness scale in detecting obstructive sleep apnea: A bivariate meta-analysis. Sleep Med Rev 2017;36:57-70.
5. Steffy DD, Tang CS. Radiographic evaluation of sleep-disordered breathing. Radiol Clin 2018;56:177-85.
6. Chang HP, Chen YF, Du JK. Obstructive sleep apnea treatment in adults. Kaohsiung J Med Sci 2020;36:7-12.
7. Mouhanna-Fattal C, Papadopoulos M, Bouserhal J, Tauk A, Bassil-Nassif N, Athanasiou A. Evaluation of upper airway volume and craniofacial volumetric structures in obstructive sleep apnea adults: A descriptive CBCT study. Int Orthod 2019;17:678-86.
8. Buchanan A, Cohen R, Looney S, Kalathingal S, De Rossi S. Cone-beam CT analysis of patients with obstructive sleep apnea compared to normal controls. Imaging Sci Dent 2016;46:9-16.
9. Chen H, Li Y, Reiber JH, de Lange J, Tu S, van der Stelt P, *et al*. Analyses of aerodynamic characteristics of the oropharynx applying CBCT: Obstructive sleep apnea patients versus control subjects. Dentomaxillofac Radiol 2018;47:20170238.
10. Fransson AM, Kowalczyk A, Isacsson G. A prospective 10-year follow-up dental cast study of patients with obstructive sleep apnea/snoring who use a mandibular protruding device. Eur J Orthod 2017;39:502-8.
11. Enciso R, Nguyen M, Shigeta Y, Ogawa T, Clark GT. Comparison of cone-beam CT parameters and sleep questionnaires in sleep apnea patients and control subjects. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:285-93.
12. Miyao E, Noda A, Miyao M, Yasuma F, Inafuku S. The role of malocclusion in non-obese patients with obstructive sleep apnea syndrome. Intern Med 2008;47:1573-8.
13. Nikolopoulou M, Aarab G, Ahlberg J, Hamburger HL, de Lange J, Lobbezoo F. Oral appliance therapy versus nasal continuous positive airway pressure in obstructive sleep apnea: A randomized, placebo-controlled trial on temporomandibular side-effects. Clin Exp Dent Res 2020;6:400-6.
14. Alsufyani NA, Al-Saleh MA, Major PW. CBCT assessment of upper airway changes and treatment outcomes of obstructive sleep apnea: A systematic review. Sleep Breath 2013;17:911-23.
15. Araie T, Okuno K, Ono Minagi H, Sakai T. Dental and skeletal changes associated with long-term oral appliance use for obstructive sleep apnea: A systematic review and meta-analysis. Sleep Med Rev 2018;41:161-72.
16. Yu C, Ahn HW, Kim SH. Three-dimensional morphological evaluation of the hard palate in Korean adults with mild-to-moderate obstructive sleep apnea. Korean J Orthod 2018;48:133-42.
17. Kecik D. Three-dimensional analyses of palatal morphology and its relation to upper airway area in obstructive sleep apnea. Angle Orthod 2017;87:300-6.
18. Maeda K, Tsuiki S, Fukuda T, Takise Y, Inoue Y. Is maxillary dental arch constriction common in Japanese male adult patients with obstructive sleep apnea? Eur J Orthod 2014;36:403-8.
19. Berwig LC, da Silva AMT, Côrrea ECR, de Moraes AB, Montenegro MM, Ritzel RA. Hard palate dimensions in nasal and mouth breathers from different etiologies. J Soc Bras Fonoaudiol 2011;23:308-14.
20. Kikinis R, Pieper SD, Vosburgh KG. 3D Slicer: A platform for subject-specific image analysis, visualization, and clinical support. Intraoperative Imaging and Image-Guided Therapy. Springer; 2014. p. 277-89.
21. Camacho M, Capasso R, Schendel S. Airway changes in obstructive sleep apnea patients associated with a supine versus an upright position examined using cone beam computed tomography. J Laryngol Otol 2014;128:824-30.
22. Gurgel ML, Junior CC, Cevidanes LHS, de Barros Silva PG, Carvalho FSR, Kurita LM, *et al*. Methodological parameters for upper airway assessment by cone-beam computed tomography in adults with obstructive sleep apnea: A systematic review of the literature and meta-analysis. Sleep Breath 2022;27:1-30.
23. Tourne LP. The long face syndrome and impairment of the nasopharyngeal airway. Angle Orthod 1990;60:167-76.
24. Tanaka Y, Honda Y. Nasal obstruction as a cause of reduced PCO_2 and disordered breathing during sleep. J Appl Physiol (1985) 1989;67:970-2.
25. Bergman RT. Cephalometric soft tissue facial analysis. Am J Orthod Dentofacial Orthop 1999;116:373-89.
26. Hida W, Okabe S, Miki H, Kikuchi Y, Kurosawa H, Takishima T, *et al*. Submental stimulation and supraglottic resistance during mouth breathing. Respir Physiol 1995;101:79-85.
27. Cistulli PA. Craniofacial abnormalities in obstructive sleep apnea: Implications for treatment. Respirology 1996;1:167-74.
28. Bresolin D, Shapiro PA, Shapiro GG, Chapko MK, Dassel S. Mouth breathing in allergic children: Its relationship to dentofacial development. Am J Orthod 1983;83:334-40.
29. Harari D, Redlich M, Miri S, Hamud T, Gross M. The effect of mouth breathing versus nasal breathing on dentofacial and craniofacial development in orthodontic patients. Laryngoscope 2010;120:2089-93.
30. Seto BH, Gotsopoulos H, Sims MR, Cistulli PA. Maxillary morphology in obstructive sleep apnea syndrome. Eur J Orthod 2001;23:703-14.