Original Article

HEALTH SCIENCES MEDICINE

DOI: 10.32322/jhsm.1124276

J Health Sci Med 2022; 5(5): 1355-1360

Assessment of posterior tilting of the hyoid bone in relation to carotid atherosclerosis: A CBCT study

Nagihan Koç

Hacettepe University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Ankara, Turkey

Cite this article as: Koç N. Assessment of posterior tilting of the hyoid bone in relation to carotid atherosclerosis: A CBCT study. J Health Sci Med 2022; 5(5): 1355-1360.

ABSTRACT

Aim: The present study aimed to investigate whether the presence and areal and volumetric measurements of the unilateral extra-cranial carotid artery calcifications (ECACs) are associated with posterior tilting of the hyoid bone.

Material and Method: A total of 658 cone-beam computed tomography (CBCT) scans were screened for the presence of ECACs. The calcifications were categorized as unilateral (right or left) or bilateral. Study group was consisted of cases with unilateral ECACs. A control group without ECACs matching with study group by age and gender was created. Volumetric and areal measurements in the ECAC group were done by using Mimics Medical software. Posterior tilting of the hyoid bone in relation to mid-sagittal plane and the dimension of posterior inclination through the greater horns were measured on i-Cat Vision software.

Results: In total, 71 (10.8%) ECACs (30 bilateral and 41 unilateral) were detected. Study group consisted of 41 (6.2%) unilateral ECAC cases [25 (61%) females and 16 (39%) males]. Gender and age distributions were similar between ECAC and control groups. No significant difference between two groups was found considering the prevalence of posterior tilting of the hyoid bone (63.4% vs. 43.9%, p=0.240). Similarly, there was no significant difference in the mean dimension of posterior inclination between groups (2.48±2.12 mm. vs. 2.24±1.47 mm, p=0.646). The volume and areal measurements of calcifications were not correlated with the dimension of posterior inclination of the hyoid bone.

Conclusion: Posterior tilting of the hyoid bone may be a frequent finding in cases of unilateral ECAC. However, the present findings suggest that no significant relationship exists between the presence of unilateral ECACs and posterior tilting of the hyoid bone.

Keywords: Carotid artery, cone-beam computed tomography, hyoid bone, vascular calcification

INTRODUCTION

The calcified carotid artery atheroma is of great importance as it represents an increased risk of stroke (cerebrovascular accident - CVA) which is a major global cause of morbidity and mortality (1). Regarding the evaluation of the patients with carotid artery calcifications (CACs), there are a number imaging modalities including ultrasonography, magnetic resonance imaging, computed tomography (CT), and angiography (2).

Calcifications in the cervical region are named as extra-cranial CACs (ECACs). In dentistry, there has been a growing interest in detecting calcifications in this region on maxillofacial images since the visualization of the lesions on panoramic radiographs firstly reported in the literature in 1981 (3). More recently, the ability of cone-beam CT (CBCT) imaging to show the presence, course, and the severity of the CACs have been described in various studies (4-8).

Cerebrovascular accidents correlated with mechanical interference between cervical structures and carotid arteries have been reported in the literature (9-11). There also have been some papers describing the impingement or compression of the internal carotid arteries by hyoid bone and trauma caused by the greater horn of the hyoid bone resulting in stenosis or traumatic pseudoaneurysm of the carotid arteries (12-14). In a recent report, a case of hyoid bone compressing the carotid artery with its right greater horn tilted posteriorly has been described (15).

Based on previous findings, it was suggested that anomalous position of the hyoid bone can provoke the formation of local calcification in the cervical region (9, 15) and may be a frequent finding in cases of ECACs. The present study aimed to investigate whether the presence and areal and volumetric measurements of the unilateral ECACs are associated with posterior tilting of the hyoid bone.

Corresponding Author: Nagihan Koç, nagihan.koc@hacettepe.edu.tr

Received: 31.05.2022 **Accepted:** 01.08.2022

This work is licensed under a Creative Commons Attribution 4.0 International License.

MATERIAL AND METHOD

This retrospective study was approved by the Research Ethics Board of Hacettepe University in Ankara, Turkey (Date: 15/10/2019, Decision No: 2019/24-28). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

CBCT images obtained between January and June 2019 were retrieved from the imaging database of Department of Dentomaxillofacial Radiology. All examinations were belonged to patients 40 years of age or older (4, 7) and requested for different diagnostic tasks such as evaluation of trauma, complications of dental and maxillofacial pathologies, and implant treatment planning. The initial sample consisted of 1264 images. The scans including C2 to C4 vertebral levels were screened (16). Following the exclusion of the scans with inadequate field of view (n=570) and motion or metal artefacts (n=36), the final sample of 658 images were obtained and selected for evaluation.

CBCT examinations were obtained with an i-Cat Next Generation device (Imaging Sciences International, Hatfield, PA, USA). The imaging protocol was: 120 kVp, 3–8 mA, 16x13 cm field-of-view, 0.20-mm voxel size, and 26.9-s scan time. The scans were imported into i-CAT Vision software and were viewed on a 24-inch LCD monitor.

All examinations were conducted by an oral and maxillofacial radiologist (N.K.) with at least 7 years of experience in CBCT imaging. Each CBCT data set was evaluated regarding the presence of any calcification. The examiner was blinded to the patient's medical and dental history and other clinical and radiographic findings. However, the age and gender of the patient was accessible.

The image analysis was performed by evaluating the axial, coronal, and sagittal multiplanar reconstructions (MPR) and the ECACs were identified as described previously in the literature (4,17,18): in axial sections, calcifications located lateral to the anterior tubercle of the transverse processes; in coronal sections, lateral to the anterior tubercle of the cervical vertebrae; in sagittal sections, medial and inferior to the angle of the mandible. The slice thickness was set at 0.2 mm. The presence of calcification was confirmed when it was detected in at least three sequential slices. The calcifications were categorized as unilateral (right or left) or bilateral.

A total of 71 (10.8%) ECACs (30 bilateral and 41 unilateral) were detected. Of these unilateral ECAC cases (n=41, 6.2%) were included in the study group. A control group (n=41) was created by matching records without ECACs by age and gender, which was selected from the final sample of 658 images.

CBCT data were exported as DICOM files for unilateral ECAC samples. The volumetric and cross-sectional area (CSA) measurements were conducted by using Mimics Medical (Materialise, Leuven, Belgium) which is a commercial software capable of segmentation process for volumetric measurements. The total volume (in cubic mm) and CSA (in square mm) measurements of the calcification were automatically calculated by the software (**Figure 1**).

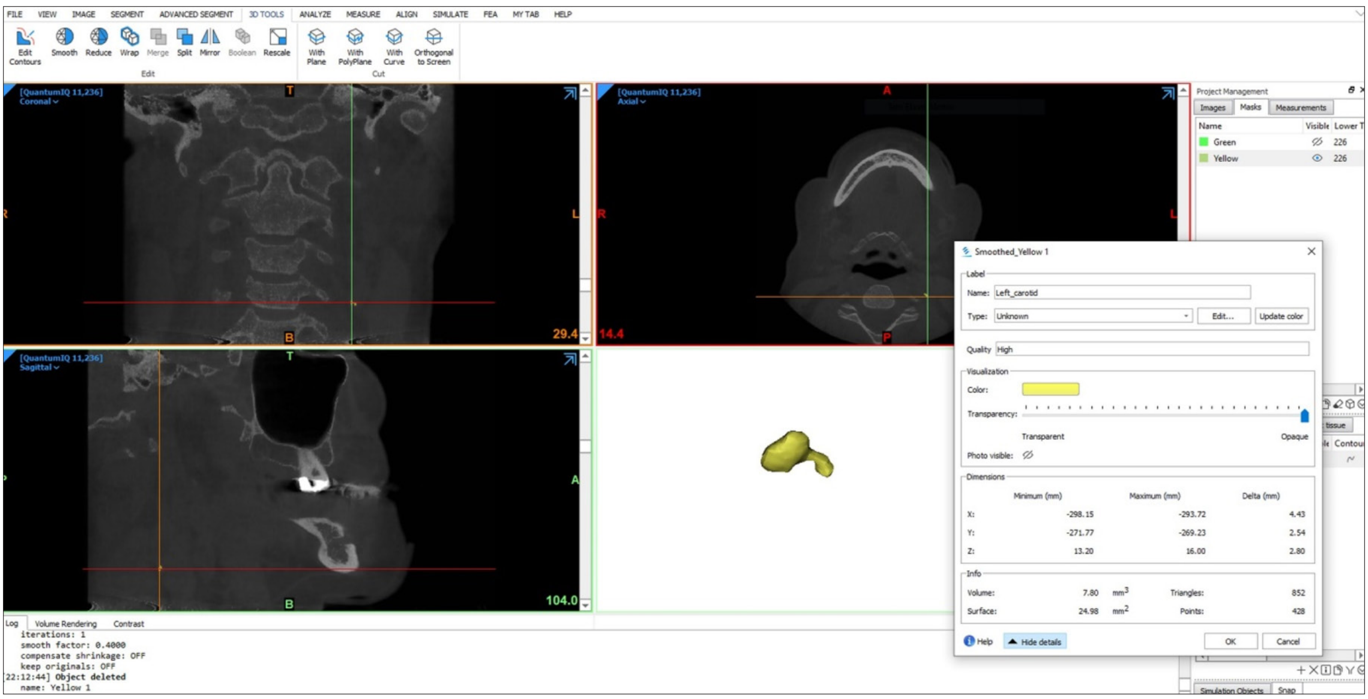

Figure 1. An example of volumetric measurement of the left extra-cranial carotid artery calcification on the Mimics software.

Measurements related to the posterior tilting of the hyoid bone were done on MPR sections of the i-Cat Vision software for unilateral ECAC group and control group. The reference points and planes were defined as follows:

- Mid-sagittal plane: Sagittal plane crossing the tip of anterior nasal spine and the posterior midpoint of the vertebral spine (**Figure 2a**) (19).
- Mid-hyoid bone: The median part of the hyoid body (**Figure 2b**).
- HLp: The most posterior point of the hyoid bone left greater horn (**Figure 2c**).
- HRp: The most posterior point of the hyoid bone right greater horn (**Figure 2c**).
- C2sp: The most superior and posterior point on the body of the second cervical vertebra (C2).
- C4ip: The most inferior and posterior point on the body of the fourth cervical vertebra (C4).
- C2sp – C4ip: Post-vertebral line (Pvl) (20, 21) (**Figure 2d**).
- HLp – Pvl: Perpendicular distance in mm between HLp to Pvl.
- HRp – Pvl: Perpendicular distance in mm between HRp to Pvl (**Figure 2e**).

The angulation between reference mid-sagittal plane and a line intersecting cervical vertabra body and the most anterior aspect of the mid-hyoid bone was measured on axial CBCT sections (**Figure 2b**). A positive degree of angulation was defined as posterior tilting of the hyoid bone on the left side. A negative degree of angulation was defined as posterior tilting on the right side. The difference between HLp – Pvl and HRp – Pvl expressed in millimeters was defined as the degree dimension of posterior tilting inclination of hyoid bone through its greater horns.

Before the analysis, head orientation was corrected on MPR sections (22): the hard palate was aligned with the horizontal plane on the mid-sagittal view, lower border of the left and right orbital ridges were aligned on the coronal view, and the left and right zygomatic arches were evaluated on the axial view.

Prior to all analysis, the examiner was calibrated with the use of 30 CBCT scans from the sample of bilateral ECACs. All measurements were done twice within an interval of 15 days.

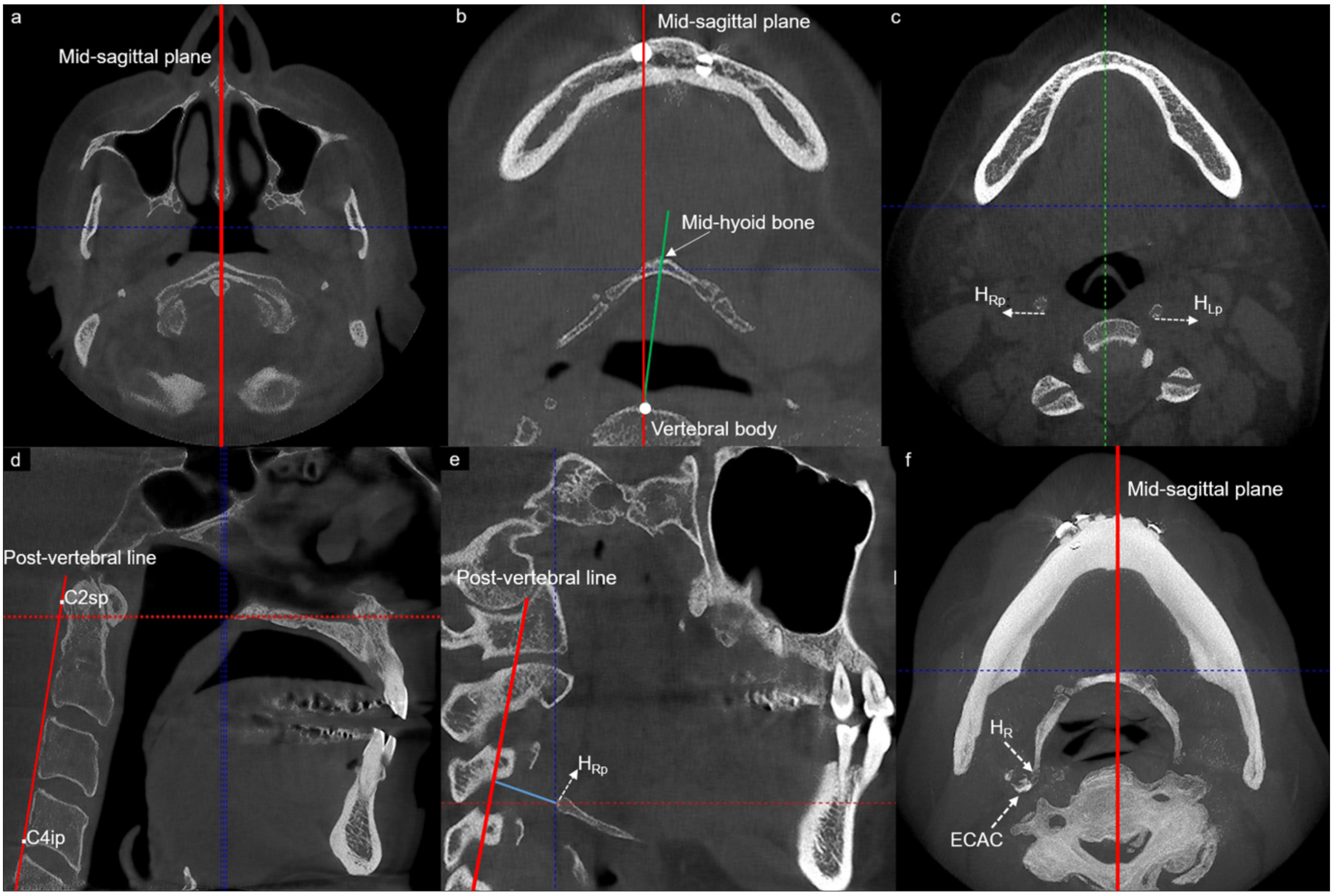

Figure 2. Axial cone-beam computed tomography (CBCT) images depicting mid-sagittal plane (a), assessment of posterior tilting of hyoid bone (b), and most posterior points of the hyoid bone left greater horn (HLp) and the right greater horn (HRp). Sagittal CBCT images showing post-vertebral line (C2sp – C4ip) (d) and the perpendicular distance from the most posterior point of the hyoid bone right greater horn (HRp) to the post-vertebral line (e). Maximum Intensity Projection (MIP) axial view (f) showing extra-cranial carotid artery calcification (ECAC) (17), hyoid bone right greater horn (HR), and the posterior tilting of the hyoid bone on right side in reference to mid-sagittal plane.

Statistical Analysis

Statistical analysis was performed using MedCalc Statistical Software version 20.018 (MedCalc Software Ltd, Ostend, Belgium). Group differences were analyzed using Mann–Whitney U test or t-test. Pearson's Chi-Square test was used to examine relationships between categorical variables. The Spearman's correlation coefficient was used to evaluate the relationship between the dimension of posterior inclination of hyoid bone and areal and volumetric measurements. Intraclass correlation coefficient (ICC) was used to evaluate the intra-observer reliability. A value of $p<0.05$ was considered statistically significant.

RESULTS

The ICC was above 0.75 for all measurements. The study group was consisted of 41 (6.2%) patients with unilateral ECACs, 25 (61%) were females and 16 (39%) were males. The control group (n=41) was matched by gender distribution. There was no significant difference between the mean ages of the ECAC group (62.97±8.72 years) and the control group (65.14±6.48), ranging from 46 to 83 years (p=0.205).

Among ECAC group, the overall mean volume was 10.52±13.91 mm^3 (ranging between 0.18 and 51.65 mm^3), while the overall mean CSA was 29.45±30.67 mm^2 (ranging between 1.90 and 117.32 mm^2).

Posterior tilting of the hyoid bone on calcification side (**Figure 2f**) was detected in 26 cases (63.4%) in ECAC group and in 18 cases (43.9%) in the control group. In 15 cases (36.6%) among the ECAC group, either tilting of the hyoid bone towards the unaffected side or no posterior tilting was detected. The number of cases without posterior tilting of the hyoid bone was 23 (56.1%) in the control group. There was no significant difference between the groups regarding the prevalence of posterior tilting of the hyoid bone (**Table 1**, p=0.240).

The mean dimension of posterior inclination of the hyoid bone was 2.48±2.12 mm in ECAC group, whereas that was 2.24±1.47 mm in the control group (p=0.646).

Table 1. Distribution (right, left, and absent) and frequency of posterior tilting of hyoid bone according to case and control groups.

Control Group	Case Group			Total n (%)	P value
	Right n (%)	Left n (%)	Absent n (%)		
Right	6 (14.6)	4 (9.8)	3 (7.3)	13 (31.7)	0.240*
Left	1 (2.4)	0 (0.0)	4 (9.8)	5 (12.2)	
Absent	8 (19.5)	7 (17.1)	8 (19.5)	23 (56.1)	
Total	15 (36.5)	11 (26.9)	15 (36.6)	41 (100.0)	

*Pearson's Chi-Square test

The Spearman's correlation coefficient showed no significant correlation between dimension of posterior inclination of the hyoid bone and volume and CSA measurements of the ECACs (**Table 2**).

Table 2. Spearman's correlation coefficient for dimension of posterior inclination of hyoid bone and volume and cross-sectional area measurements of the extra-cranial carotid artery calcifications

	Dimension of posterior inclination of hyoid bone	
	r	p value
Calcification volume (mm^3)	0.13	0.51
Cross-sectional area (mm^2)	0.10	0.60

DISCUSSION

The present study was designed to determine a possible association between the occurrence of ECACs and anomalous position of the hyoid bone by means of posterior tilting of the greater horns. Such association could be established based on the previous findings which suggest adjacent bony structures in the cervical region may interfere with carotid arteries (12-15).

The hyoid bone with its body and greater and lesser horns, is often an overlooked small anatomical structure, although it gives attachment to several muscles and ligaments of the neck and plays a vital role in the craniomandibular functions (23). Hyoid bone position has been frequently studied in relation to oropharyngeal space dimensions (24), facial growth patterns (25), craniofacial anomalies (20), obstructive sleep apnea syndrome (26), myofascial pain (27), atypical deglutition (28), and temporomandibular joint disc displacement (29). The hyoid position in relation to carotid artery diseases as its proximity to the carotid bifurcation level is a rarely studied phenomenon, although there are several case reports describing CVAs due to unilateral compression of the hyoid bone through its greater horn (9,11,12,23,30). Of these, a recent case report has also demonstrated a dynamic evidence for the compression of internal carotid artery (ICA) by the greater horn of the hyoid bone during swallowing (31). A common conclusion based on these reports suggests that a protruding hyoid greater horn may cause repetitive traumatic forces that induce changes in the artery wall. As a result of this, disturbed blood flow and high wall shear stress may lead to the formation of unilateral atherosclerosis (9). The present study is motivated by these studies and particularly focused on the unilateral CACs. To the best of the author's knowledge, this study is first to evaluate proximity of the hyoid bone greater horns to the cervical region by considering the posterior tilting of hyoid bone in terms of its divergence to mid-sagittal plane. Posterior tilting of the hyoid bone was observed with more than half cases (63.4%) in ECAC group. The prevalence of posterior tilting of hyoid bone in control group was lower (43.9%) than study group. However, the difference was not statistically significant.

The reference points used for the evaluation of dimension of posterior inclination of hyoid bone in the present study were the most posterior point of the greater horn of the hyoid bone and a line connecting the most posterior points of the C2–C4 vertebra bodies (Post-vertebral line-Pvl). The difference between measured dimensions of each greater horn to Pvl indicated a degree of proximity of hyoid bone to cervical region on related side. The mean dimension of posterior inclination of hyoid bone in the present study was similar in ECAC and control groups. Moreover, the volume and CSA measurements of the calcifications were not correlated with posterior tilting of the hyoid bone, which means neither the volume or dimension of the calcification was increased with the dimension of posterior inclination of hyoid bone. The present findings suggest that there is no significant relationship between the presence of unilateral ECACs and the prevalence of posterior tilting of hyoid bone. This is also consistent with a recent study by Siegler et al. (32), which investigated the proximity of the hyoid bone greater horn to the ICA on CT angiography.

The prevalence of unilateral and bilateral ECACs in this study (n=71, 10.8%) was consistent with the reported range (2.8-17.56%) in CBCT studies (33-36) in the literature but was lower than in some previous studies (4,7), which reported a considerably higher prevalence rate up to 42.88%. This might be attributed to sample selection criteria and population characteristics.

This study has some limitations. The first one is that the sample size was relatively small, which might not be sufficient to establish significant associations. Secondly, a longitudinal cohort may determine if there is a causal relationship between hyoid tilting and ECACs. Third, other adjacent structures, such as styloid processes were not taken into consideration. Fourthly, anatomic variations in the carotid vessels, the course of the carotid artery, and the degree of stenosis could not be evaluated on CBCT. Finally, inter-observer agreement for measurements were not calculated.

In conclusion, the present study is the first to investigate the relationship between the presence of unilateral ECACs and the prevalence of posterior tilting of the hyoid bone and suggests no significant relationship exists between these two entities, although posterior tilting of the hyoid bone may be a frequent finding in cases of unilateral ECACs.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was approved by the Non-Interventional Clinical Research Ethics Board of the Hacettepe University (Date: 15/10/2019, Decision No: 2019/24-28).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The author has no conflicts of interest to declare.

Financial Disclosure: The author declared that this study has received no financial support.

Author Contributions: The author declares that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version

Acknowledgements: The author would like to thank Dr. Hatice Boyacıoğlu Doğru and Dr. Sinem Coşkun for their support during the Research Ethics application process.

REFERENCES

1. Hollander M, Bots ML, Del Sol AI, et al. Carotid plaques increase the risk of stroke and subtypes of cerebral infarction in asymptomatic elderly: the Rotterdam study. Circulation 2002; 105: 2872-7.
2. MacDonald D. Oral and maxillofacial radiology: a diagnostic approach. 2nd ed. New Jersey: Wiley-Blackwell; 2019.
3. Friedlander AH, Lande A. Panoramic radiographic identification of carotid arterial plaques. Oral Surg Oral Med Oral Pathol 1981; 52: 102-4.
4. Damaskos S, Tsiklakis K, Syriopoulos K, van der Stelt P. Extra-and intra-cranial arterial calcifications in adults depicted as incidental findings on cone beam CT images. Acta Odontol Scand 2015; 73: 202-9.
5. Damaskos S, da Silveira HL, Berkhout EW. Severity and presence of atherosclerosis signs within the segments of internal carotid artery: CBCT's contribution. Oral Surg Oral Med Oral Pathol Oral Radiol 2016; 122: 89-97.
6. Damaskos S, Aartman IH, Tsiklakis K, van der Stelt P, Berkhout WE. Association between extra- and intracranial calcifications of the internal carotid artery: a CBCT imaging study. Dentomaxillofac Radiol 2015; 44: 20140432.
7. Mutalik S, Tadinada A. Assessment of relationship between extracranial and intracranial carotid calcifications-a retrospective cone beam computed tomography study. Dentomaxillofac Radiol 2019; 48: 20190013.
8. Erbay S, Han R, Baccei S, et al. Intracranial carotid artery calcification on head CT and its association with ischemic changes on brain MRI in patients presenting with stroke-like symptoms: retrospective analysis. Neuroradiology 2017; 49: 27-33.
9. Abdelaziz OS, Ogilvy CS, Lev M. Is there a potential role for hyoid bone compression in pathogenesis of carotid artery stenosis? Surg Neurol 1999; 51: 650-3.
10. Chuang WC, Short JH, McKinney AM, Anker L, Knoll B, McKinney ZJ. Reversible left hemispheric ischemia secondary to carotid compression in Eagle syndrome: surgical and CT angiographic correlation. AJNR Am J Neuroradiol 2007; 28: 143-5.

11. Renard D, Azakri S, Arquizan C, Swinnen B, Labauge P, Thijs V. Styloid and hyoid bone proximity is a risk factor for cervical carotid artery dissection. Stroke 2013; 44: 2475-9.

12. Kölbel T, Holst J, Lindh M, Mätzsch T. Carotid artery entrapment by the hyoid bone. J Vasc Surg 2008; 48: 1022-4.

13. Martinelli O, Fresilli M, Jabbour J, Di Girolamo A, Irace L. Internal Carotid Stenosis Associated with Compression by Hyoid Bone. Ann Vasc Surg 2019; 58: 379.e1-.e3.

14. Schneider CG, Kortmann H. Pseudoaneurysm of the common carotid artery due to ongoing trauma from the hyoid bone. J Vasc Surg 2007; 45: 186-7.

15. Tawk S, Desuter G, Jamali S. Recurrent Syncope upon Deglutition. J Belg Soc Radiol 2018; 102: 55.

16. Mirjalili SA, McFadden SL, Buckenham T, Stringer MD. Vertebral levels of key landmarks in the neck. Clin Anat 2012; 25: 851-7.

17. Scarfe W, Farman A. Soft tissue calcifications in the neck: Maxillofacial CBCT presentation and significance. AADMRT Currents 2010; 2: 3-15.

18. Angelopoulos C. Cone beam tomographic imaging anatomy of the maxillofacial region. Dent Clin North Am 2008; 52: 731-52.

19. Wan F, Wang M, Guan M, Wang J, Liu M, Pan X. Analysis of three dimensional oropharyngeal airway and hyoid position in retrognathic adolescent patients. Orthod Waves 2019; 78: 102-110.

20. Pinto RO, Peixoto AP, Pinto ADS, et al. Hyoid Bone Position and Head Posture in Patients With Richieri-Costa Pereira Syndrome (EIF4A3 Mutations). J Craniofac Surg 2020; 31: e356-e9.

21. Gu G, Gu G, Nagata J, et al. Hyoid position, pharyngeal airway and head posture in relation to relapse after the mandibular setback in skeletal Class III. Clin Orthod Res 2000; 3: 67-77.

22. Tso HH, Lee JS, Huang JC, Maki K, Hatcher D, Miller AJ. Evaluation of the human airway using cone-beam computerized tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108: 768-76.

23. Plotkin A, Bartley MG, Bowser KE, Yi JA, Magee GA. Carotid Artery Entrapment by the Hyoid Bone-A Rare Cause of Recurrent Strokes in a Young Patient. Ann Vasc Surg 2019; 57: 48.e7-.e1.

24. da Costa ED, Roque-Torres GD, Brasil DM, Bóscolo FN, de Almeida SM, Ambrosano GMB. Correlation between the position of hyoid bone and subregions of the pharyngeal airway space in lateral cephalometry and cone beam computed tomography. Angle Orthod 2017; 87: 688-95.

25. Mortazavi S, Asghari-Moghaddam H, Dehghani M, et al. Hyoid bone position in different facial skeletal patterns. J Clin Exp Dent 2018; 10: e346-e51.

26. Kurbanova A, Szabo BT, Aksoy S, et al. Comparison of hyoid bone morphology between obstructive sleep apnea patients and healthy individuals. Int J Clin Pract 2021; 75: e15004.

27. Pettit NJ, Auvenshine RC. Change of hyoid bone position in patients treated for and resolved of myofascial pain. Cranio 2020; 38: 74-90.

28. Machado Júnior AJ, Crespo AN. Radiographic position of the hyoid bone in children with atypical deglutition. Eur J Orthod 2012; 34: 83-7.

29. An JS, Jeon DM, Jung WS, Yang IH, Lim WH, Ahn SJ. Influence of temporomandibular joint disc displacement on craniocervical posture and hyoid bone position. Am J Orthod Dentofacial Orthop 2015; 147: 72-9.

30. Liu S, Nezami N, Dardik A, Nassiri N. Hyoid bone impingement contributing to symptomatic atherosclerosis of the carotid bifurcation. J Vasc Surg Cases Innov Tech 2020; 6: 89-92.

31. Yamaguchi Y, Saito A, Ohsawa Y, Nagasawa H, Wada M. Dynamic 3D-CT angiography during swallowing for diagnosing hyoid bone or thyroid cartilage compression-induced thromboembolism. Radiol Case Rep 2020; 15: 1468-72.

32. Siegler JE, Konsky G, Renner C, et al. Carotid artery atherosclerosis is not associated with hyoid proximity: Results from a cross-sectional and longitudinal cohort study. Clin Imaging 2019; 58: 39-45.

33. Togan B, Gander T, Lanzer M, Martin R, Lübbers HT. Incidence and frequency of nondental incidental findings on cone-beam computed tomography. J Craniomaxillofac Surg 2016; 44: 1373-80.

34. Kurtuldu E, Alkis HT, Yesiltepe S, Sumbullu MA. Incidental findings in patients who underwent cone beam computed tomography for implant treatment planning. Niger J Clin Pract 2020; 23: 329-36.

35. Kachlan MO, Yang J, Balshi TJ, Wolfinger GJ, Balshi SF. Incidental findings in cone beam computed tomography for dental implants in 1002 patients. J Prosthodont 2021; 30: 665-75.

36. Barghan S, Tahmasbi Arashlow M, Nair MK. Incidental findings on cone beam computed tomography studies outside of the maxillofacial skeleton. Int J Dent 2016; 2016: 9196503.