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WILL CONE-BEAM COMPUTED TOMOGRAPHY ADD NEW TO THE STYLOHYOID COMPLEX ANALYSIS?

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ABSTRACT

Objectives: The aim of the present study was to assess the role of CBCT in the assessment of the length, angulations, and different morphologic variations of the stylohyoid complex (SHC).

Methods: CBCT scans of 112 subjects (41 males, 71 females, age range 5-52 years old) were included in the study. SHC was evaluated bilaterally. Length, anteroposterior angulation (APA), mediolateral angulation (MLA), morphologic and calcification patterns were evaluated. 25th -75th percentiles were calculated to detect the normal length and angulation ranges.

Results: The normal range of the SHC length was 25.5-33.6 mm. SHC elongation was found in 32 cases (28.6%). APA and MLA normal ranges were (24.9o-34.2o and 66.6o-72.8o respectively). Males showed higher mean values than females regarding the SHC length and angulations with statistically significant difference in APA and MLA between both sexes. New morphologic pattern was detected in (2.7%) of cases. Normal length (Patterns A, B, C, D) was found in (74.65%) of the bilaterally evaluated SHC. Among the elongation cases, calcified SHC (Patterns F-K and the new pattern) was the most prevalent (17.8%). Absent SP was observed in (0.45%). The most prevalent calcification pattern was type B.

Conclusion: CBCT revealed a new SHC morphologic pattern that may contribute to the proposed classification in literature. CBCT is a valuable imaging modality for accurate identification and analysis of the SHC in terms of length, angulations, and anatomic discrepancy.

KEYWORDS: Cone-beam computed tomography; Elongated styloid process; Ossification; Stylohyoid complex.

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INTRODUCTION

The stylohyoid chain or stylohyoid complex (SHC) is a part of the human skull that encompasses the styloid process (SP), the stylohyoid ligament (SHL), and the lesser cornu of the hyoid bone.[1] The SHC is subdivided into four parts:1) The tympanohyal (THy), forming the base of the SP, 2) The stylohyal (SHy), forming the main body of the SP, 3) The ceratohyal (CHy), forming the SHL, which extends from the tip of SP to the lesser horn of the hyoid bone, and 4) The hypohyal (HHy), forming the lesser horn of the hyoid bone representing the connection between the SHL and the hyoid bone. [2,3]

Many important vital structures exist nearby the SHC: the internal carotid artery, internal jugular vein, and cranial nerves X, XI, and XII lie on its medial side, and the external carotid artery lies laterally. [4-6] As such, elongated or abnormally deviated SHC may irritate these structures, and thought to account for the related syndromes (Eagle's syndrome and stylohyoid syndrome). [4,5] Arising symptoms include headache, facial pain, sore throat, sensation of foreign body in the pharynx, dysphagia, neck pain especially on rotating the head, dizziness, tinnitus, and otalgia. [7,8]

The high incidence of long SHC with low clinical manifestations, and the presence of symptoms without the evidence of elongation were previously mentioned. [4,9] Therefore, not only the length should be considered as the causative pathogenic factor of styloid syndromes, but the angulation is also important to be evaluated to explain these manifestations. [3,10]

In addition to the clinical significance, SHC calcification is important from the medicolegal and forensic aspects. SHC calcification may result in blood flow disturbances in the external or internal carotid arteries that may be a cause of sudden death. [11] Operations of the cervical region in case of elongated SP or complete ossification of the SHC have the risk of their fracture and can cause complications during intubations. [12,13] Furthermore, SHC elongation helps in the identification of unknown individuals. [12]

Radiographic examinations are important in SHC evaluation. Long ago, panoramic radiographs were used for this purpose; however, limitations exist due to the 2D nature of plain radiographs that challenges the measurement of the full dimension and angulation of the SHC. [14,15] Computed tomography (CT) and cone beam computed tomography (CBCT) are preferred as they provide 3D assessment of anatomic structures; however, in CT imaging higher radiation dose is required and image degradation may result from slight movement. CBCT provides 3D imaging with a lower radiation dose making it more valuable for maxillofacial imaging. [3,15-17]

Therefore, the aim of the present study was to assess the role of CBCT in the assessment of the length, angulations, and different morphologic variations of the SHC that may be of aid in clinical, surgical, forensic, and educational purposes.

MATERIAL AND METHODS

The present study was performed after approval by the institutional ethics committee, Faculty of Dentistry, Cairo University (RIB number 411020)

Study design

Sample size calculation

Sample size was calculated based on mean and standard deviation of the SHC length based on similar previous studies. The sample size obtained was 112 with 95% confidence and 90% power.

Study sample

The study sample included CBCT scans of 112 subjects (41 males and 71 females) with age range of 5-52 years old. For each subject, the SHC of both right and left sides were assessed; thereby, a total of 224 SHC (82 for males and 142 for females) were examined.

Eligibility criteria

CBCT images with maxillofacial field of view of both males and females were included in the study. CBCT images with a small field of view and images of patients with trauma, pathology, syndromes, or any type of anomalies were excluded.

CBCT imaging

This was a retrospective study carried on CBCT scans of patients presented with various dental problems. Images were obtained from the Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University. Images were obtained using Planmeca Promax 3D-Mid CBCT scanner (Planmeca, Helsinki, Finland) with the following parameters: (tube voltage: 90 kV, tube current: 8 mA, exposure time: 13.5 s, FOV: 20x10 cm, voxel size: 0.4 mm). The CBCT scan DICOM data files were imported and analyzed using the In Vivo Dental software (Anatomage, San Jose, Calif).

Blinding

The images were exported anonymously and coded that all the case information as the patient's age and sex were hidden during the image analysis procedure.

CBCT imaging analysis

Images were evaluated twice with a one-month interval to assess the intra-observer reliability and validity of measurement methods.

All images were analyzed as follows:

Identification of the SP

The preciseness of any measurement on radiographs depends on several factors; the most essential are the visibility of the landmarks, and the projection. [18] The SP is a slender, smooth, cylindrical bony projection of the temporal bone posterior to the tympanic plate and vaginal process. [19] Usually, the vaginal process of the temporal bone hides its attachment leading to difficult identification. Therefore, meticulous inspection of the SP origin in the coronal, axial and sagittal planes was performed.

Measuring the length of the SHC

This was measured on the sagittal plane as the distance between the base of the SP and the tip of the ossified SHC. If partial ossification of the SHL was observed, the measurement was made including the non-ossified part. [3] **(Figure 1A)**

Measuring the anteroposterior angulation (APA) of the SHC

The APA is also called: the sagittal angle. This was performed on reconstructed maximum intensity projection (MIP) lateral cephalometric images. A horizontal line was passed from the external acoustic foramen to the infraorbital margin along the Frankfort plane. Then, a vertical line was drawn perpendicular to this horizontal line. The sagittal angle was defined as the angle between the vertical line and the long axis of the SHC. [17, 20, 21] **(Figure 1B)**

Measuring the mediolateral angulation (MLA) of the SHC

The MLA is also called: the transverse angle. This was measured on the coronal plane as the angle of intersection of the line connecting both bases of the right and left SP and the long axis of the SHC. [3,20,21] **(Figure 1C)**

Determining the morphology of the SHC

The morphologic appearance of the SHC depends on the degree of calcification of the SHC components. Therefore, SHC morphology was identified as being one of 12 types as stated by MacDonald-Jankowski [22], where the degree of calcification was described according to the center of calcification involved; Region 1, tympanohyal (R1THy); Region 2, stylohyal (R2 SHy); Region 3, ceratohyal (R3 CHy); Region 4, hypohyal (R4 HHy). In his study on panoramic radiographs, the mandibular foramen was used to distinguish regions 1 and 2 that are present down to the mandibular

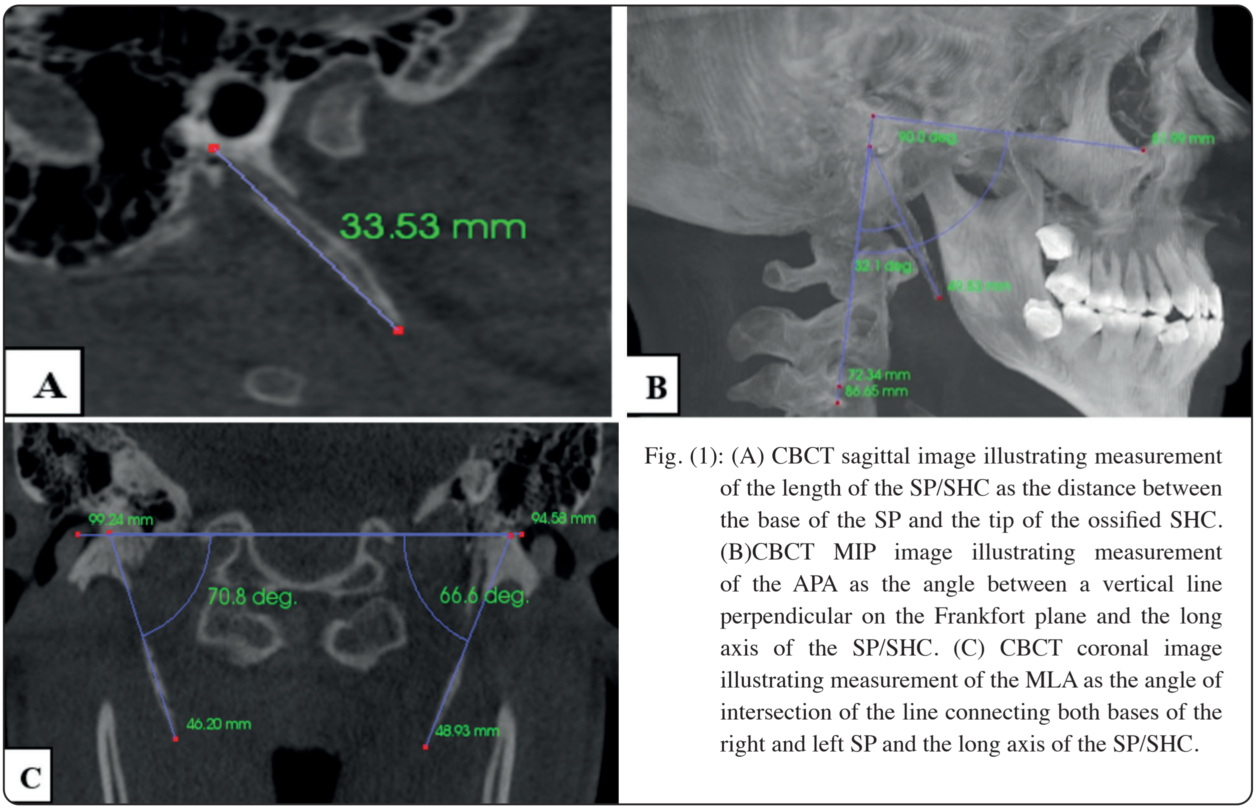

Fig. (1): (A) CBCT sagittal image illustrating measurement of the length of the SP/SHC as the distance between the base of the SP and the tip of the ossified SHC. (B)CBCT MIP image illustrating measurement of the APA as the angle between a vertical line perpendicular on the Frankfort plane and the long axis of the SP/SHC. (C) CBCT coronal image illustrating measurement of the MLA as the angle of intersection of the line connecting both bases of the right and left SP and the long axis of the SP/SHC.

foramen from regions 3 and 4 that extend below the mandibular foramen. However, in CBCT the condition is different; the scan re-orientation for proper visualization of the SHC could not display the SHC and the mandibular foramen at the same slice. As such, in the current study, mandibular ramus was taken as a reference to the 4 regions. On the MIP lateral cephalometric images, the ramus was divided into 3 thirds for regions 1, 2, 3 respectively and region 4 location was set below the mandibular angle till the hyoid bone.

The twelve morphologic patterns of SHC were as follows: Pattern: (A) THy alone (B) SHy alone (C) THy and SHy, separate (D) THy and SHy, continuous (E) THy, SHy, and CHy, continuous (F) THy, SHy, and CHy, separate (G) THy and SHy, continuous, but separate from CHy (H) SHy, and CHy, separate (I) SHy, and CHy, continuous, but separate from THy (J) CHy alone (K) CHy and HHy continuous (may include calcification in one other region) (L) absent styloid process. Patterns (A-D) are normal SHC, pattern (E) is elongated SP, patterns (F-K) are calcified SHL, pattern (L) is absence of SHC. Diagrammatic representation of the 12 SHC morphologic patterns is shown in **Figure 2.** [23]

Determining the calcification pattern of the SHC

Four calcification patterns were classified according to Langlais et al.: [24] (A) Calcified outline: a process with thin radiopaque border. (B) Partially calcified: a process that has a thicker radiopaque outline and small radiolucent cores. (C) Nodular complex: a knobby or scalloped outline that may be partially or completely calcified. (D) Completely calcified: totally radiopaque process with no interior radiolucency.

Statistical analysis

Statistical analysis was performed using excel 365 with real statistics resource pack version 7.1. Data was tested for normality using Shapiro-Wilk test. ICC was used to test the intra-observer agreement (below 0.50: poor, between 0.50 and 0.75: moderate, between 0.75 and 0.90: good, above 0.90: excellent). Sample description was done using quartiles, mean, and standard deviation. Regression analysis was used to correlate between variables. Two independent sample T-test was used for comparison with alpha value 0.05, confidence interval 95%, thus P-value < 0.05 was considered statistically significant.

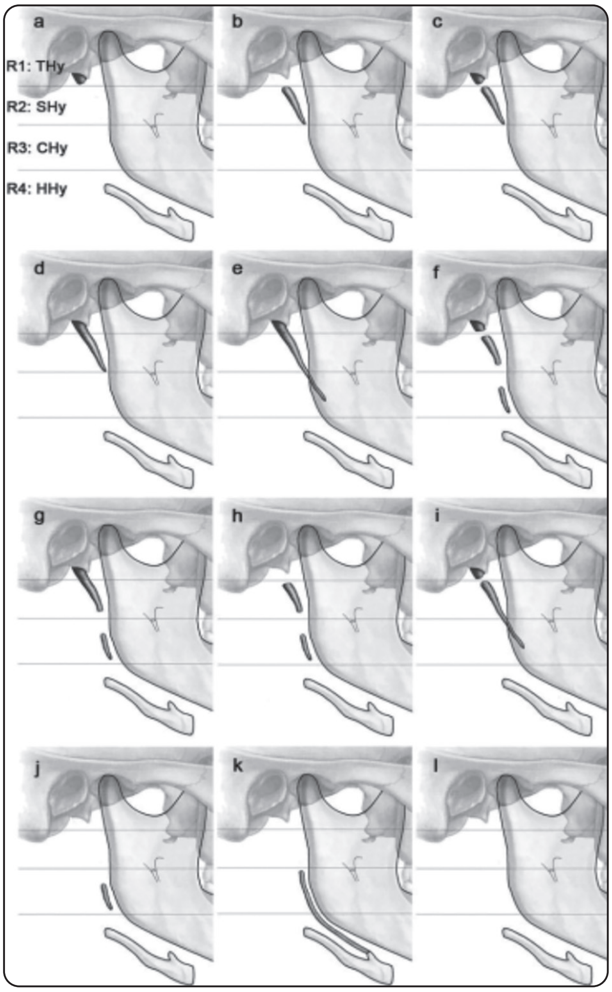

Fig. (2) The twelve patterns of stylohyoid complex calcification as proposed by MacDonald-Jankowski. [22] R1 THy: Region 1 Tympanohyal, R2 SHy: Region 2 Stylohyal, R3 CHy: Region 3 Ceratohyal, R4 HHy: Region 4 Hypohyal. Pattern: (a) THy alone (b) SHy alone (c) THy and SHy, separate (d) THy and SHy, continuous (e) THy, SHy, and CHy, continuous (f) THy, SHy, and CHy, separate: (g) THy and SHy, continuous, but separate from CHy (h) SHy, and CHy, separate (i) SHy, and CHy, continuous, but separate from THy (j) CHy alone: (k) CHy and HHy continuous (may include calcification in one other region) (l) absent styloid process. (Figure quoted from Alpoz, et al. 2013). [23]

RESULTS

There was an excellent intra-observer agreement regarding the measurements of SHC length, APA and MLA (ICC = 0.997, 0.994 and 0.975 respectively).

Table 1 shows comparison between the values for SHC length, APA and MLA in males and females. Males showed higher mean values than females in all the parameters with statistically significant difference in APA and MLA between both sexes.

TABLE (1): Comparison of the means, standard deviations, maximum and minimum values of SHC length, APA, and MLA between males and females

	Parameters	Males	Females	Total
Length	Mean	32.9	31.9	32.3
	Standard deviation	1.6	1	0.9
	Maximum	82.3	76.3	82.3
	Minimum	8.2	5.5	5.5
	P value	0.95		
APA	Mean	31	28.7	29.5
	Standard deviation	0.8	0.6	0.5
	Maximum	45.8	44.8	45.8
	Minimum	12.3	15.3	12.3
	P value	0.02*		
MLA	Mean	70.5	69.3	69.7
	Standard deviation	0.4	0.4	0.5
	Maximum	78.9	81.2	81.2
	Minimum	61.7	57.8	57.8
	P value	0.04*		

*APA: anteroposterior angulation, MLA: mediolateral angulation, *P< 0.05 is statistically significant.*

No statistically significant differences were found between right and left sides; however, the right MLA was greater than the left one that was significant in females and in the total sample **(Table 2)**.

Table 3 shows the percentiles/quartiles of SHC length, APA, and MLA. The 25th–75th percentiles were considered as the normal ranges.

TABLE (2): Comparison of the means, standard deviations, maximum and minimum values of SHC length, APA, and MLA between right and left sides in males and females

	Parameters	**Males**		**Females**		**Total**	
		Right	Left	Right	Left	Right	Left
Length	Mean	32.9	32.8	32.3	31.4	32.5	31.9
	Standard deviation	14.1	14.7	13.2	11.5	13.5	12.7
	Maximum	77.4	82.3	76.3	64.2	77.4	82.3
	Minimum	17.7	8.1	5.5	6.8	5.5	6.8
	P value	0.99		0.73		0.80	
APA	Mean	30.8	31.1	28.5	28.8	29.4	29.6
	Standard deviation	6.4	7.4	6.4	7.2	6.5	7.3
	Maximum	44.4	45.8	40	44.8	44.4	45.8
	Minimum	12.9	12.3	15.3	15.5	12.9	12.3
	P value	0.87		0.83		0.79	
MLA	Mean	70.9	70	70	68.5	70.3	69.1
	Standard deviation	4.2	3.4	4.9	4.3	4.6	4
	Maximum	78.9	76.4	81.2	80.3	81.2	80.3
	Minimum	61.7	64.5	61.2	57.8	61.2	57.8
	P value	0.33		0.04*		0.02*	

APA: anteroposterior angulation, MLA: mediolateral angulation, *P< 0.05 is statistically significant.

TABLE (3): Q1 (25th Percentile) and Q3 (75th Percentile) of SHC length, APA, and MLA in males, females, and in the total study sample

Parameters	**Males**		**Females**		**Total**	
	Q1 25th Percentile	Q3 75th Percentile	Q1 25th Percentile	Q3 75th Percentile	Q1 25th Percentile	Q3 75th Percentile
Length	25.3225	34.5575	25.6775	33.5525	25.5975	33.665
APA	27.175	35.5	23.6	33.675	24.925	34.225
MLA	67.575	72.875	66.35	72.8	66.675	72.8

APA: anteroposterior angulation, MLA: mediolateral angulation, Q1: quartile 1, Q3: quartile 3

TABLE (4): Prevalence of different morphologic patterns

Morphology	A	B	C	D	E	F	G	H	I	J	K	L	New pattern
Males (n=82)													
No	1	0	42	17	5	1	3	0	5	0	5	1	2
%	1.2	0	51.2	20.7	6.1	1.2	3.7	0	6.1	0	6.1	1.2	2.4
Females (n=142)													
No	4	2	67	34	11	12	4	0	4	0	0	0	4
%	2.8	1.4	47.2	24	7.7	8.5	2.8	0	2.8	0	0	0	2.8
Total (n=224)													
No	5	2	109	51	16	13	7	0	9	0	5	1	6
%	2.25	0.9	48.7	22.8	7.1	5.8	3.1	0	4	0	2.2	0.45	2.7

For morphologic pattern definitions see Figure 2 and 3

Based on the percentile normal ranges, SHC elongation was found in 32 cases (28.6%) of the total sample; 12 males and 20 females. Among males, 10 cases showed bilateral elongation and 2 cases unilateral (24.4% and 4.9% respectively). Among females, 14 cases showed bilateral elongation and 6 cases unilateral (19.7% and 8.5% respectively).

No correlation was found between age and SHC length, APA, or MLA [R squared (R^2) = 0.004, 0.006 and 0.005 respectively]. Similarly, no correlation was found between length and APA or MLA (R^2 = 0.001 and 0.002 respectively). Also, no correlation was found between APA and MLA (R^2 = 0.001).

Table 4 shows the distribution of the 12 morphologic patterns. During image analysis, a new morphological pattern was observed which is THy and CHy separate, this was classified as: new pattern. Normal length (Patterns A, B, C, D) was found in 167 SHC (74.65%), where pattern (C) was the most prevalent (48.7%). Among the elongation cases, calcified SHC (Patterns F-K and the new pattern) was the most prevalent (17.8%) followed by elongated SP (pattern E) which occurred in (7.1%) of the cases. Unilaterally absent SP was observed in one male only (0.45%). Morphologic patterns observed in the study are shown in **figure (3)**

Distribution of the calcification patterns of the identified SHC is shown in **table (5)** and **(Figure 4)**. The most prevalent calcification pattern was type B (partial) among both males and females.

TABLE (5): Distribution of the calcification patterns of the identified SHC

Calcification pattern	A	B	C	D
Males (n=81)				
No	5	67	7	2
%	6.2	82.7	8.6	2.5
Females (n=142)				
No	2	119	12	9
%	1.4	83.8	8.5	6.3
Total (223)				
No	7	186	19	11
%	3.1	83.4	8.5	4.9

For calcification pattern definitions see Figure 4

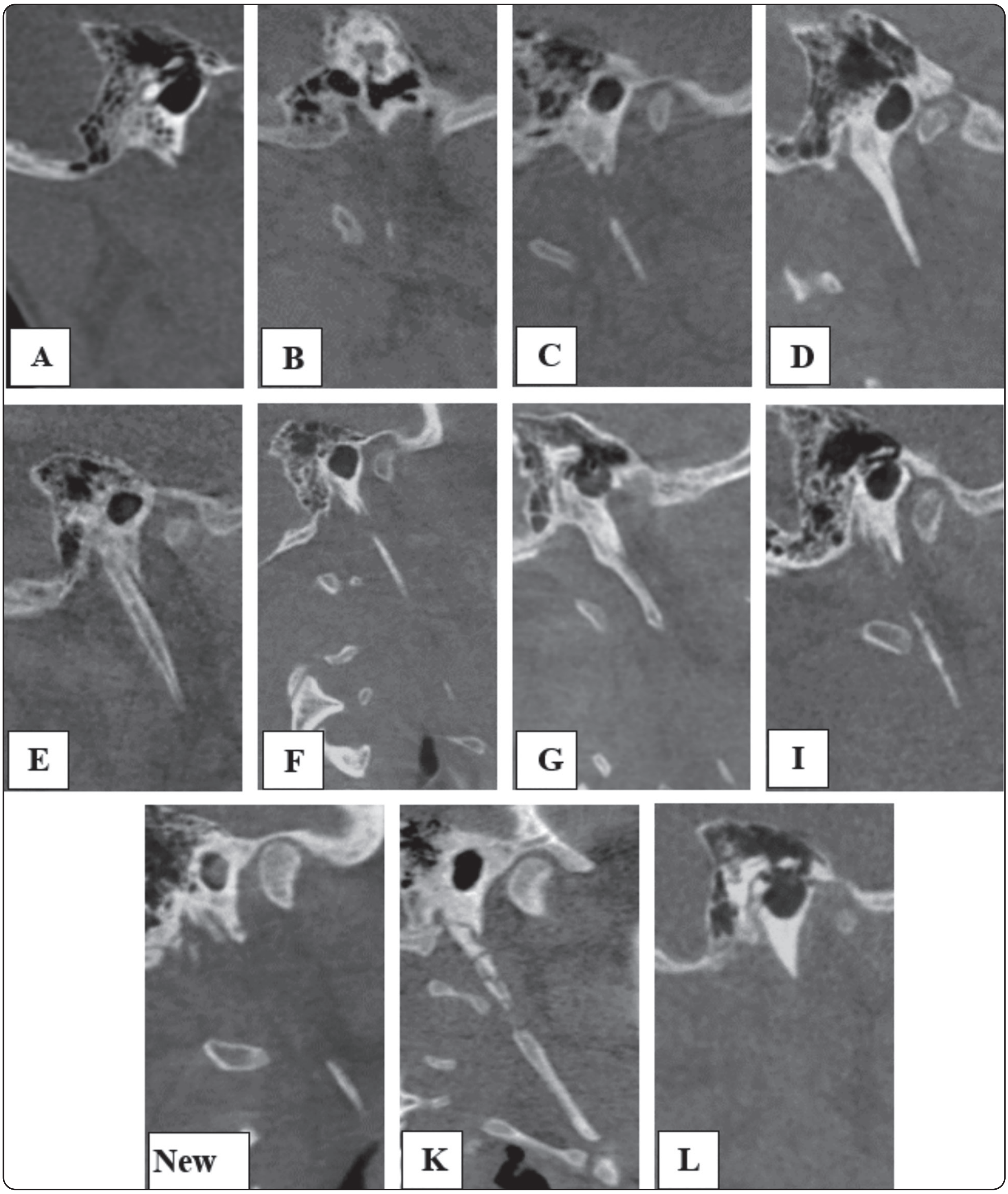

Fig. (3) CBCT images revealing the SHC morphologic patterns observed in the study. (A) THy alone (B) SHy alone (C) THy and SHy, separate (D) THy and SHy, continuous (E) THy, SHy, and CHy, continuous (F) THy, SHy, and CHy, separate (G) THy and SHy, continuous, but separate from CHy (I) SHy, and CHy, continuous, but separate from THy (New) THy and CHy separate (K) CHy and HHy continuous (may include calcification in one other region) (L) absent styloid process (THy: Tympanohyal, SHy: Stylohyal, CHy: Ceratohyal, HHy: Hypohyal).

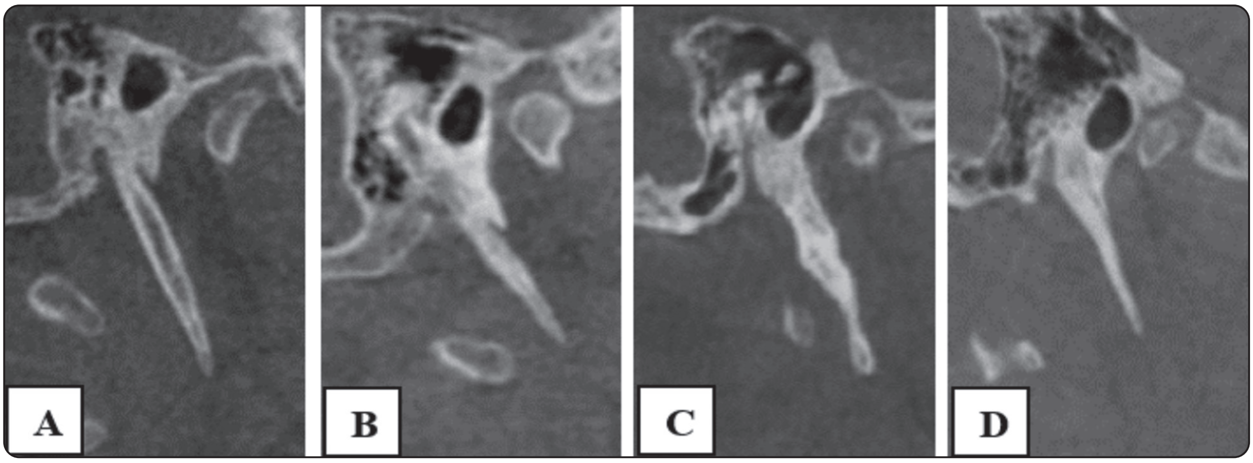

Fig. (4) CBCT images revealing the four calcification patterns of the SHC: (A) Calcified outline: a process with thin radiopaque border. (B) Partially calcified: a process that has a thicker radiopaque outline and small radiolucent cores. (C) Nodular complex: a knobby or scalloped outline that may be partially or completely calcified. (D) Completely calcified: totally radiopaque process with no interior radiolucency.

DISCUSSION

Awareness of the variability of SHC is very important in many aspects. It is essential for clinicians to be aware of this in the diagnosis and management of atypical pain in the head and neck region. Further, it is of special interest in forensic practice and medicolegal problems.[19]

In our study, males showed higher mean values of the SHC length than females (32.9 mm and 31.8mm respectively) with no statistical significance. Similar values were reported by Ramadoss and Sha [25] where mean length was 32.10mm in males and 31.62mm in females. Many previous studies showed higher mean values of males than females with no significant difference. [3,16,26] This can be accepted as normal variation between genders where males tend to have larger bones and are more muscular than females.[27] Other studies found significant differences between genders. [1,2,18,20,28] Further, previous studies found no statistically significant differences between right and left SHC lengths. [20,26] Our results confirm those findings.

Differences in the normal SHC length existed between studies. Using panoramic radiographs, it was accepted that 30 mm length was the upper limit of the normal SHC. [14,29] Using 3D CT volume rendered images, Ramadan et al. [3] reported 27 mm and Onbas et al. [26] reported 26.8 mm as normal lengths. However, Okur et al. [30] found that the mean length in their control group was 40 mm. Using CBCT, Andrei et al., [10] and Kalabalık and Şahin [17] reported mean lengths of 35.09mm and 37.06 mm respectively. In the present study the mean length was 32.2 mm. These differences among studies are mostly due to variations in the imaging modalities, measurement methods as well as the examined populations.

Because of these variations among the normal populations, instead of the mean values, the 25th–75th percentile was proposed as the normal range by Ramadan et al.[3] who found 21-30 mm as the normal range of the SHC length. The present study revealed normal range of 25.5-33.6 mm. Approximating this value to the nearest mm, a value of 34mm was considered the upper normal limit and values more than this were considered elongation. This was near to Natsis et al. [19] where the normal range was 18-33mm. Ilgüy et al. [20] reported a range of 19-28 mm. On the other hand, Jung et al. [18] suggested that only SP of more than 45 mm should be considered elongated.

SHC elongation was observed in 28.6% of the study sample. Among the CBCT studies, elongation prevalence ranged from 15.1% to 56.6%. [1,8,13,15, 26] This concurred with Nogueira-Reis et al. [31] in their systematic review who stated that the prevalence of the elongated SP ranged from 1.3 to 94.8%, with an overall prevalence of 30.2% which is close to the present study. This wide range is mostly due to variability in determining the normal range of SHC length among studies as well as the inherent population variations. [10, 16]

Further, SHC elongation was observed bilaterally in 21.4% and unilaterally in 7.2% of the cases. This was in accordance with previous studies where bilateral involvement surpassed the unilateral. [1,8, 31] However, Scaf et al. [29] had contradictory result with unilateral elongation of the right side being more common.

No correlation was found between length and age which concurred with previous studies. [1,8,32] Instead, positive correlation was observed in other studies. [14,18]

Regarding the APA, there was a diversity in the measurement methods among studies. So, only studies with similar measurement method to the present study were compared. In the present study, total sample mean APA was 29.5º and females showed statistically significant smaller values than males (28.7º and 31º respectively). İlgüy et al. [20] found mean APA of 25.6° (27.1° and 23.8° in females and males respectively), and Chu et al. [34] reported mean value of 26.67º (27.62º and 25.51º in females and males respectively). In contrast to our work, both studies found that mean APA values of females were significantly greater than males. Several studies on the position of the hyoid bone revealed that the hyoid bone position in females is superior and posterior to that of males. [35,36] This in turn will make the SHC direction more posterior in females, which is most probably the cause of the narrower APA in females found in the current work.

In the present study, the normal APA range was 24.9º - 34.2º. Ilgüy et al. [20] normal range was 22º-28º. The normal range is important as narrower angle indicates the deviation of the SHC more posteriorly which may cause compression of the cranial nerves IX-XII, internal carotid artery, and internal jugular vein between the ossified SHC and lateral part of the atlas; however, wider angle indicates anterior deviation, which leads to impinging on the tonsillar fossa. These deviations in angulation are to a great extent responsible for the patient complaints. [18, 26, 37]

In the present study, mean MLA of the total sample was 69.7 º. Similar mean values were found by Basekim et al. [16] (69.5°). Slightly higher mean values were reported by Buyuk et al., [1] Ramadan et al. [3] and Onbas et al. [26] (70.81 º, 72 º and 72.7° respectively). Lower mean values were reported by Ilgüy et al., [20] Anderi et al. [10] and Chu et al. [34] (66.4º, 66.74° and 66.9° respectively).

The mean MLA was significantly greater in males than females (70.4 º and 69.3 º respectively). This was similar to Basekim et al., [16] (70.5° and 68.7°) and Chu et al. [34] (67.54° and 66.38°) for males and females respectively. On the contrary, greater values for female subjects were found by Buyuk et al. [1] (70.34° and 72.23° for males and females respectively). Anatomically speaking, male bones are larger than female ones. As for the hyoid bone, when it is larger, the direction of the SHC towards the attachment to the lesser cornu of the hyoid bone will be more lateral which in turn increases the MLA in males.

In the whole sample, the mean right MLA was greater than the left (70.3° and 69.1° respectively) which agrees with Ramadan et al. [3] and Chu et al. [34]. However, Yılmaz et al. [33] reported greater MLA values for the left side.

The normal MLA range was (66.6º-72.8º) which was close to Basekim et al., [16] Ramadan et al., [3] and Ilgüy et al. [20] who reported normal MLA ranges of (65°-75°), (67°- 76°), and (63°-69°) respectively. Narrow MLA angle may cause compression of internal carotid artery, while wide angles may cause compression of the external carotid artery account for the patient symptoms. [3,36]

In the present study, no correlation was found between length and APA which agrees with previous reported results. [10, 25] Further, no correlation was found between length and MLA similar to previous studies. [1, 10, 16, 26] Also, no correlation was found between APA and MLA.

In the present study, among the normal SHC, the most prevalent pattern was C followed by D. MacDonald-Jankowski [22] and Okabe et al. [28] found pattern D was the most prevalent followed by B. Alpoz et al. [23] and Omami [38] found pattern D the most prevalent followed by C. It is worth noting that the pattern of elongated SHC differs among populations; in the present study on Egyptians, the most prevalent elongation pattern was the calcified SHL (Patterns: F-K and the new pattern). Omami [38] and MacDonald-Jankowski [22] found similar result among Libyans and Londoners respectively. However, elongated SP (pattern E) was the most prevalent among the Hong Kong Chinese, [22] Japanese, [28] and Turkish populations [23]

In the present study, styloid process was unilaterally absent in one male only (0.45%). In studies using panoramic radiographs, MacDonald-Jankowski [22] reported absence of SP in 58 cases (3.5%), Okabe et al. [28] reported 35 cases (5.3%), and Omami [38] reported 121 cases (3.8%). Regarding the 3D CT studies, Basekim et al. [16] and Ramadan et al. [3] reported 5 cases (1.8% and 2.5% respectively).

As revealed, in studies using CT the prevalence of SP absence is less than observed in panoramic radiographs. The major disadvantage of panoramic radiographs is the superimposition of the mandible and base of the skull on the SP which impairs proper identification. [22, 39] This justifies the low prevalence of SP absence found in the present CBCT study. Further, Frommer [4] in his study on dissected human SHC did not find any case in which the SP was completely absent; instead, a vestigial tympanohyal in the form of a reduced process was present.

A noteworthy finding in the present study was that two morphologic patterns (Patterns: H and J) were not detected. These patterns do not comprise the THy part. CBCT aided in the identification of the THy part which is the origin of the SP, and this resulted in the new pattern detected in the present study (THy and CHy separate). Anatomically, the THy part is hidden by the vaginal process of the temporal bone, [19] thereby requires careful inspection to assess whether it is present or completely absent. CBCT multiplanar images aided a lot in THy identification and this justifies why the aforementioned two morphologic types were not detected in this study. Based on the study results, it is recommended that new classification comprising 11 morphologic patterns better be employed when CBCT scans are performed.

Attention to the SHC morphologic variations is essential for the surgical procedures performed in this area. [17,33] Moreover, there might be a lack of neurovascular damage in cases with partially ossified SHC; however, mild clinical symptoms may occur that may be misdiagnosed if a routine CT is not performed for suspected cases to rule in or out such ossifications. [10]

In the current study, the most prevalent calcification pattern was type B (partial). This was similar to CBCT studies by Öztunç et al., [8] Javadian Langaroodi et al., [40] and Chu et al. [34] However, Buyuk et al. [1] and Kailasam et al. [13] found that type A (calcified outline) was the most frequent.

A limitation of the present study was that it was a retrospective CBCT study, so no clinical data about the patient complains were available. As such, further studies on the relationship between SHC elongation, angulations, and the occurrence and severity of clinical symptoms is recommended to evaluate the association of symptoms with SHC variations.

From the present study results, the answer to the author question “Will CBCT add new to the SHC analysis?” is certainly “Yes”. CBCT allowed for precise identification of the SP origin, and thereby length measurement. Further, APA and MLA angulations of SHC were precisely assessed on the multiplanar reformatted images. Morphologic patterns in my opinion were revisited as CBCT allowed for the proper visualization of the THy part, which is usually hidden by superimpositions in conventional radiographs, this in turn made a change where a new pattern was discovered, and some previous patterns may no longer be present.

CONCLUSION

CBCT revealed a new morphologic pattern of SHC that may contribute to the proposed classification in literature. CBCT is a valuable imaging modality that aided in the accurate identification and analysis of the SHC in terms of length, angulations, and anatomic discrepancy.

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