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Evaluation of the relationship between stylohyoid complex morphology and maxillary/mandibular position using cone beam computed tomography

D. Yılmaz[1], K. Orhan[1, 2], E. Cesur[3]

[1]*Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ankara University, Ankara, Turkey*
[2]*OMFS IMPATH Research Group, Department of Imaging and Pathology, Faculty of Medicine, University of Leuven and Oral and Maxillofacial Surgery, University Hospitals Leuven, Belgium*
[3]*Private Practice, Orthodontics, Ankara, Turkey*

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Background: *The aim of this study was to examine the morphologic features of the stylohyoid complex (SHC) and its relation to maxillomandibular position using three-dimensional cone beam computed tomography (CBCT) images.*
Materials and methods: *CBCT images from 157 individuals (74 females, 83 males) were analysed in this study. SHC length, width, and sagittal and transverse angles were measured. The subjects were grouped as skeletal class I, II, and III in order to determine the relative positions of the maxilla and mandible in the sagittal plane and as hypodivergent, normodivergent, and hyperdivergent according to the vertical rotation of the mandible in relation to the skull base. Mann-Whitney U and Kruskal-Wallis H tests were used for statistical analysis.*
Results: *Mean SHC length was 23.56 ± 8.05 mm on the right side and 22.0 ± ± 6.51 mm on the left; mean SHC width was 3.31 ± 1.40 mm on the right and 2.93 ± 1.30 mm on the left. Mean sagittal angle was 27.43 ± 6.75° on the right side, 27.70 ± 6.51° on the left; mean transverse angle was 70.39 ± 4.59° on the right side and 71.79 ± 4.99° on the left. The only significant difference based on skeletal classification was greater SHC length among males compared to females in the class III group ($p < 0.05$).*
Conclusions: *No significant relationship was observed between SHC morphology and position of the maxilla or mandible. However, the gender difference observed among class III subjects suggests that SHC morphology may be affected by craniofacial morphology. Maxillofacial surgeons should investigate this anatomical landmark variation before surgical interventions involving this region, such as temporomandibular joint procedures.* (Folia Morphol 2020; 79, 1: 148–155)

Key words: stylohyoid complex, maxillo-mandibular relation, mandibular rotation, cone beam computed tomography

Address for correspondence: Prof. Dr. K. Orhan, Ankara University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Ankara, Besevler, Turkey 06560, OMFS IMPATH Research Group, Department of Imaging and Pathology, Faculty of Medicine, University of Leuven and Oral and Maxillofacial Surgery, University Hospitals Leuven, Leuven, Belgium, e-mail: call53@yahoo.com; kaan.orhan@kuleuven.be

INTRODUCTION

Processus styloideus (SP) is a cylindrical bony projection that extends from the inferior surface of the temporal bone immediately anterior to foramen stylomastoideum and continues as ligamentum stylohyoideum (SHL), which terminates in attachment to cornu minus of os hyoideum [7, 25]. The major structures attached to the SP are musculus stylopharyngeus, musculus stylohyoideus and musculus styloglossus, and ligamentum stylohyoideum and ligamentum stylomandibulare [13]. Musculus stylohyoideus originates from the SP and attaches to the cornu majus of os hyoideum, and its main function is to lift os hyoideum while swallowing.

Together, the SP, SHL, and cornu minus of os hyoideum form the stylohyoid complex (SHC). While the peak of SP is located lateral to the pharyngeal wall between the internal and external arteries, the close association of the SHC with nervus glossopharyngeus, nervus vagus, nervus accessorius, and nervus hypoglossus as well as vascular structures such as vena jugularis interna and arteria maxillaris is important [24, 27].

Various studies on the morphological properties of the SHC have reported pathological abnormalities such as SP elongation, SHL ossification, and os hyoideum elongation [6, 7, 11, 18]. Due to the close proximity of the SHC to neurovascular structures, such pathological anomalies can give rise to a variety of symptoms. These symptoms were first described in 1937 by Eagle, and include shooting pain from the pharynx to the ear, difficulty swallowing, and foreign body sensation in the throat, comprising a condition known as Eagle syndrome. In addition to elongation or calcification of the SHC, it is believed that variations in angulation and thickness may also create pressure on the neighbouring anatomic structures, thereby causing discomfort [6, 14, 24].

Although several methods are used to visualise the SHC and its calcification, including panoramic radiographs, posteroanterior images, and lateral cephalometric radiographs [1, 20, 23, 25], cone beam computed tomography (CBCT) has become the preferred imaging modality in recent years because it provides more detailed images and more accurate data [6, 20].

According to the functional matrix theory, skeletal units (the bony structures supporting and protecting the functional units) grow and adapt according to changes occurring in the functional units (muscles, cavities, neurovascular structures, etc.) [21]. In other words, the growth and formation of skeletal structures is influenced by functional processes. Although the development of the maxillomandibular complex is affected by neighbouring structures, changes in these structures and their functions may in turn impact other structures. The relationship between os hyoideum and various orthodontic anomalies has been studied previously [9, 12, 19], but there are no studies in the literature regarding the connection between os hyoideum and os temporale.

The aim of this study was to investigate the possible correlation of maxillary and mandibular malocclusions with SHC morphology, particularly the incidence and variations of SHL calcification.

MATERIALS AND METHODS

This retrospective study included CBCT data from 157 patients (74 females, 83 males; minimum age: 18 years, maximum age: 73 years, mean age: 37.4 years) who were treated at the Ankara University Dentistry Faculty for various reasons. Ethical approval for the study was obtained from the Ankara University Faculty of Dentistry Ethics Committee (IRB number: 36290600/11). Using the studies and the data from the literature, sample size was calculated using the G*power 3.0.10 programme (Universität Düsseldorf, Germany). Considering an alpha significance level of 0.05 and a statistical power of 0.80, the study required at least 42 patients in each group.

Exclusion criteria for the study included:
- presence of bone disease (osteoporosis, etc.);
- history of trauma;
- history of surgery in the maxillofacial region;
- presence of congenital anomalies (cleft lip/palate, etc.);
- history of tumours or similar malignant pathology in the maxillofacial region.

In addition, CBCT scans with poor image quality that precluded effective evaluation were excluded from the study.

Three-dimensional (3D) images were obtained using a standard imaging protocol and a Planmeca 3D MAX device (Planmeca, Helsinki, Finland). All constructions were performed on a 21.3-inch flat-panel colour-active matrix TFT medical display (NEC MultiSync MD215MG, Munchen, Germany) with a resolution of 2048 × 2560 at 75 Hz and 0.17-mm dot pitch operated at 11.9 bits. Heads of the patients were fixed to minimise movement artefact. CBCT images were exported in Digital Imaging and Communications in

Medicine (DICOM) format. Romexis 3.7 (Planmeca, Helsinki, Finland) software programme was used to generate 3D models, measurements and orthodontic analysis. The software is capable of correction of head virtually. Thus, if any discrepancies were seen in the head position, using the software capabilities, the Frankfurt line and head position were adjusted and standardised to the same position for all patients in a semi-automatic fashion.

The SHC was evaluated using a modified version of the classification created by O'Carroll and Jackson [22]. According to this system, the vertical position of the SP is evaluated as either higher than foramen mandibulae or aligned with/lower than foramen mandibulae.

Sagittal images were used to measure the length and width of the SP and to calculate the distance between the base of the SP and the highest point of SHC ossification (Fig. 1). If segmental ossification was observed, the non-ossified regions were included in the measurement. SHC width was measured as the widest distance visible on the sagittal plane [6]. In order to evaluate the angulation of the SP in sagittal sections, the Frankfort horizontal plane (FH) passing through the highest point of porus acusticus externus and the lower edge of aditus orbitalis was formed and a vertical line was made 90° to this plane. The sagittal angle was measured as the angle between the long axis of the SP and the vertical line descending from the FH (Fig. 2A). The transverse angle was measured on anteroposterior images as the angle between the long axis of the SP and the line connecting the SP bases on each side (Fig. 2B) [14].

ANB angle was used to determine the position of the maxilla and mandible relative to each other in the sagittal plane (Fig. 3) [29, 30]. This angle is determined as the angle between point A, which is the most concave point of the anterior maxilla, the nasion (N), which is the anteriormost point of sutura frontonasalis, and point B, which is the deepest point of the anterior mandible. Steiner claimed that 2 ± 2° should be accepted as the average size of this angle. Based on ANB angle, the subjects were grouped into sagittal skeletal classes as follows:
- class I: ANB 0–4°; mandible is in a normal position relative to the maxilla;
- class II: ANB > 4°; mandible is retruded and/or maxilla is protruded;
- class III: ANB < 0°; mandible in protruded and/or maxilla is retruded.

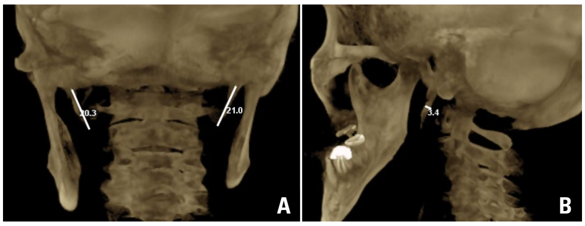

Figure 1. Three-dimensional reconstructed cone beam computed tomography images showing the measurement of the length of the processus styloideus (SP) (**A**) and measurement of the width of the SP (**B**).

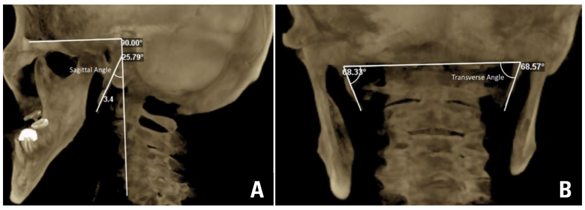

Figure 2. Three-dimensional reconstructed cone beam computed tomography images showing the measurement of the sagittal angle (**A**) and measurement of the transverse angle (**B**).

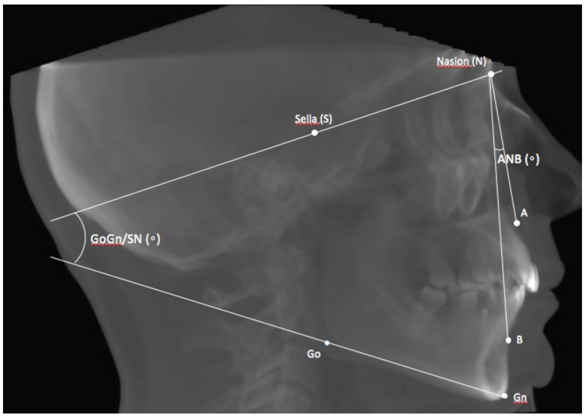

Figure 3. Three-dimensional reconstructed cone beam computed tomography images showing the measurement of ANB and GoGn/SN angles.

The GoGn/SN angle was used to enable classification in the vertical plane (Fig. 3) [29]. The line connecting the geometric centre of the sella turcica, or point S, and point N was used to represent the anterior cranial base [26]. The lowest and posteriormost point of angulus mandibula margin was identified as the gonion (Go), while the lowest and anteriormost point of the symphysis mandibula was accepted as the gnathion (Gn). The line connecting these two points was considered the mandibular plane. Accordingly, the angle between the anterior

cranial base and the mandibular plane was used to determine the rotational pattern and vertical orientation of the mandible. The average GoGn/SN angle is assumed to be 32°. In our study, we categorised the subjects as follows:
- normodivergent: GoGn/SN angle 32 ± 6° and mandibular rotation within normal range;
- hypodivergent: GoGn/SN angle < 26° and mandibular counterclockwise rotation; vertical dimensions are generally decreased;
- hyperdivergent: GoGn/SN angle > 38° and mandibular clockwise rotation; vertical dimensions are generally increased.

Statistical analysis

SPSS (Statistical Package for Social Sciences) 22.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All measurements were done twice by a single observer. To assess intra-observer reliability, the Wilcoxon matched-pairs signed rank test was used for repeat measurements.

The Kruskal-Wallis H test was used to compare right and left SHC morphology according to the sagittal and vertical cephalometric groups, while the Mann-Whitney U test was used for gender-based comparisons. Statistical significance was accepted at $p < 0.05$.

RESULTS

Repeated CBCT evaluation and measurements showed no significant intra-observer variation ($p > 0.05$). All measurements were found to be highly reproducible, with no significant difference between pairs of measurements made by the observer ($p > 0.05$).

The distribution of individuals according to skeletal sagittal (class I, class II, class III) and vertical (hypodivergent, normodivergent, hyperdivergent) classifications are shown in Table 1.

Descriptive statistics regarding the distribution of the subjects and the SHC length are also given in Table 1. SHC length, width, and sagittal and transversal angulations on the right and left sides are shown in Table 2.

The mean ANB and GoGn/SN angles are shown in Table 3, and no significant gender-based differences were observed in any of the groups.

Stylohyoid complex length, width, and transverse and sagittal angles did not differ significantly on the right or left side between the skeletal class I, II, and III groups (Table 4). When the same parameters were

Table 1. Distribution of patients according to gender, skeletal sagittal and vertical classifications, processus styloideus (SP) and stylohyoid complex lengths

	N	Per cent
Gender:		
Female	74	47.1
Male	83	52.9
Skeletal sagittal classification:		
Class 1	59	37.6
Class 2	74	47.1
Class 3	24	15.3
Skeletal vertical classification:		
Hypodivergent	39	24.8
Normodivergent	92	58.6
Hyperdivergent	26	16.6
SP (right):		
Higher	122	77.7
Lower	15	9.6
Aligned	20	12.7
SP (left):		
Higher	117	74.6
Lower	20	12.7
Aligned	20	12.7
Stylohyoid complex (right):		
< 30	132	84.1
≥ 30	25	15.9
Stylohyoid complex (left):		
< 30	141	89.9
≥ 30	16	10.2

Table 2. Descriptive statistics of stylohyoid complex measurements for all patients (n = 157)

	Right			Left		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum.	Maximum
Length [mm]	23.56 ± 8.05	10.7	65.2	22.0 ± 6.51	6.4	48.5
Width [mm]	3.31 ± 1.40	0,4	9.2	2.93 ± 1.30	0.3	7.3
Sagittal angle [°]	27.43 ± 6.75	8	46	27.70 ± 6.51	12	43
Transverse angle [°]	70.39 ± 4.59	59	95	71.79 ± 4.99	59	100

SD — standard deviation

Table 3. Mean, minimum and maximum values of ANB and GoGn/SN angles for study groups, and comparison of mean values between genders by Mann-Whitney U test

		Female			Male			P
		Min.	Max.	Mean ± SD	Min.	Max.		
ANB [°]	Class I	2.09 ± 1.20	0.10	3.90	2.56 ± 1.13	0.10	3.90	0.134
	Class II	6.37 ± 1.42	4.20	10	6.48 ± 2.50	4.80	15	0.411
	Class III	–3.99 ± 3.28	–11	–0.20	–3.40 ± 3.42	–11	–0.03	0.583
GoGn/SN [°]	Normodivergent	32.28 ± 3.33	26	37	31.17 ± 3.19	26	38	0.096
	Hypodivergent	21.86 ± 2.48	17	25	22.72 ± 2.82	14	25	0.151
	Hyperdivergent	44.79 ± 5.15	39	54	44.42 ± 4.14	39	52	0.938

Min. — minimum; max. — maximum; SD — standard deviation

Table 4. Comparison of stylohyoid complex measurements between classes I, II and III groups for right and left sides by Kruskal-Wallis h test

	Right					Left				
	Class I (n = 59)	Class II (n = 74)	Class III (n = 24)	h	p	Class I (n = 59)	Class II (n = 74)	Class III (n = 24)	h	p
Length [mm]	24.50 ± 9.19	23.48 ± 7.71	21.49 ± 5.60	1.7	0.436	21.74 ± 6.85	22.12 ± 6.62	22.28 ± 5.42	0.3	0.854
Width [mm]	3.26 ± 1.52	3.40 ± 1.32	3.14 ± 1.38	1.2	0.551	2.84 ± 1.32	2.99 ± 1.33	2.96 ± 1.18	0.5	0.765
Sagittal angle [°]	26.15 ± 6.52	28.31 ± 6.58	27.88 ± 7.59	4.5	0.107	26.69 ± 6.63	28.45 ± 6.25	27.88 ± 0.94	1.6	0.449
Transverse angle [°]	70.00 ± 4.07	70.62 ± 5.02	70.67 ± 4.57	0.1	0.955	71.78 ± 4.14	71.35 ± 5.48	73.17 ± 5.27	2.4	0.294

Table 5. Comparison of stylohyoid complex measurements between genders for classes I, II and III groups by Mann-Whitney U test

		Class I (n = 59)			Class II (n = 74)			Class III (n = 24)		
		Female (n = 27)	Male (n = 32)	P	Female (n = 35)	Male (n = 39)	P	Female (n = 12)	Male (n = 12)	P
RIGHT	Length [mm]	24.68 ± 8.28	24.35 ± 10.03	0.498	23.14 ± 6.28	23.78 ± 8.86	0.829	19.94 ± 5.27	23.04 ± 5.71	**0.023***
	Width [mm]	3.19 ± 1.68	3.32 ± 1.40	0.471	3.25 ± 0.89	3.54 ± 1.61	0.725	3.52 ± 1.46	3.16 ± 1.35	0.817
	Sagittal angle [°]	24.85 ± 5.99	27.25 ± 6.83	0.145	27.89 ± 7.20	28.69 ± 6.04	0.688	26.67 ± 6.62	29.08 ± 8.56	0.258
	Transverse angle [°]	69.67± 4.23	70.28 ± 3.97	0.298	69.89 ± 3.72	71.28 ± 5.92	0.274	69.92 ± 2.99	71.42 ± 5.79	0.642
LEFT	Length [mm]	22.64 ± 6.82	20.97 ± 6.89	0.294	22.20 ± 5.46	22.04 ± 5.46	0.701	20.70 ± 4.65	23.85 ± 5.86	**0.038***
	Width [mm]	2.98 ± 1.38	2.73 ± 1.27	0.568	2.83 ± 0.98	3.13 ± 1.58	0.418	2.89 ± 1.03	3.02 ± 1.36	0.885
	Sagittal angle [°]	25.89 ± 6.50	27.38 ± 6.77	0.451	28.34 ± 6.23	28.54 ± 6.36	0.807	27.58 ± 6.61	28.17 ± 7.47	0.643
	Transverse angle [°]	70.26 ± 4.06	73.06 ± 3.80	0.154	70.69 ± 4.34	71.95 ± 6.33	0.474	72.50 ± 3.94	73.83 ± 6.45	0.685

*$p < 0.05$

compared according to gender, no difference was observed between men and women in class I and class II patients. However, in the class III group, SHC on both the right and left side was longer in males than in females ($p < 0.05$; Table 5).

There were no significant differences in SHC morphological measurements in hypodivergent, normodivergent, and hyperdivergent subjects when compared between the right and left sides or by gender (Tables 6 and 7).

DISCUSSION

Previous studies suggested that dental and skeletal facial morphology may vary among different ethnic groups. Sathler et al. [28] stated that interincisal angle and overbite is smaller in Caucasians compared to Mongoloid and Brazilian-Japanese individuals. It was also concluded that craniofacial differences may be observed between Caucasians and Japanese individuals in both class II division 1 and class III malocclusions [16, 17]. So, all patients

Table 6. Comparison of stylohyoid complex measurements between normo-/hypo-/hyperdivergent groups for right and left sides by Kruskal-Wallis h test

	Right					Left				
	Normo-divergent (n = 92)	Hipo-divergent (n = 39)	Hiper-divergent (n = 26)	h	P	Normo-divergent (n = 92)	Hipo-divergent (n = 39)	Hiper-divergent (n = 26)	h	P
Length [mm]	23.87 ± 8.93	22.39 ± 5.41	24.22 ± 8.15	0.3	0.871	21.80 ± 6.15	21.45 ± 6.76	23.53 ± 7.35	1.1	0.565
Width [mm]	3.21 ± 1.34	3.55 ± 1.61	3.29 ± 1.32	0.6	0.726	2.97 ± 1.35	3.05 ± 1.23	2.59 ± 1.20	2.9	0.237
Sagittal angle [°]	27.55 ± 6.45	27.38 ± 7.61	27.08 ± 6.69	0.6	0.731	27.57 ± 6.07	28.26 ± 7.11	27.35 ± 7.25	1.2	0.553
Transverse angle [°]	70.36 ± 4.00	70.90 ± 5.92	69.77 ±4.40	0.9	0.645	71.80 ± 4.74	72.51 ± 5.59	70.65 ± 4.88	2.2	0.331

Table 7. Comparison of stylohyoid complex measurements between genders for normo/hypo/hyperdivergent groups by Mann-Whitney U test

		Normodivergent (n = 59)			Hypodivergent (n = 39)			Hyperdivergent (n = 26)		
		Female (n = 27)	Male (n = 32)	P	Female (n = 21)	Male (n = 18)	P	Female (n = 14)	Male (n = 12)	P
RIGHT	Length [mm]	23.82 ± 7.96	23.91 ± 9.66	0.651	23.13 ± 4.81	21.52 ± 6.07	0.304	24.17 ± 7.02	24.28 ± 9.64	0.918
	Width [mm]	3.04 ± 1.22	3.34 ± 1.42	0.236	3.21 ± 1.33	3.94 ± 1.84	0.278	3.71 ± 1.38	2.80 ± 1.09	0.166
	Sagittal angle [°]	26.23 ± 7.02	28.53 ± 5.88	0.157	27.81 ± 7.63	26.89 ± 7.78	0.985	27.79 ± 6.94	26.25 ± 6.58	0.455
	Transverse angle [°]	70.21 ± 4.55	70.47 ± 3.58	0.381	70.00 ± 3.78	71.94 ± 7.70	0.373	69.71 ± 4.44	69.83 ± 4.55	0.979
LEFT	Length [mm]	21.87 ± 5.00	21.75 ± 6.92	0.575	23.42 ± 6.91	19.14 ± 5.96	0.065	23.56 ± 7.19	23.50 ± 7.85	0.797
	Width [mm]	3.03 ± 1.33	2.93 ± 1.38	0.853	3.02 ± 1.04	3.09 ± 1.44	0.977	2.42 ± 0.88	2.78 ± 1.50	0.757
	Sagittal angle [°]	26.69 ± 6.08	28.21 ± 6.04	0.336	27.86 ± 6.86	28.72 ± 7.58	0.631	28.79 ± 7.52	25.67 ± 6.85	0.267
	Transverse angle [°]	70.97 ± 5.17	72.42 ± 4.35	0.089	71.48 ± 3.64	73.72 ± 7.16	0.276	70.57 ± 5.20	70.75 ± 4.71	0.777

included in this study were Caucasians to avoid confounding.

The length of the SHC varies between individuals but is accepted as 30 mm on average. İlgüy et al. [14] reported that the average SHC length was 22.25 mm in their study, and stated that normal values may range from 19 to 28 mm. They asserted that measurements above these values should be considered 'elongated'. In another study using multidetector computed tomography, the mean SP length was 26.8 mm, and 32% of the individuals had an elongated SP [24]. However, Jung et al. [18] stated that SP length had a mean of 28 mm and may vary in the 23–36 mm range. According to these authors, SP lengths greater than 45 mm should be considered elongated.

In the present study, the mean SHC length was 23.56 ± 8.05 mm on the right side and 22.0 ± 6.51 mm on the left side (Table 2). Therefore, our results support the evidence suggesting that SHC length over 30 mm may be defined as elongated. In a study by Dönmez et al. [10] conducted with CBCT images, SP length was greater than 30 mm in 15.1% of the images. Consistent with their results, we detected an 'elongated' SHC on the right side in 25 (15.9%) and on the left side in 16 (10.2%) of the 157 individuals whose CBCT images were analysed in our study (Table 1).

Individuals with longer SHC typically experience unpleasant symptoms such as pain and foreign body sensation in the throat, discomfort while swallowing, and recurrent headaches and facial pain [14]. Not only the length but also the angulation of the SHC is believed to potentially increase the pressure on neural and vascular structures, leading to symptoms or aggravating existing complaints. Başekim et al. [4] reported that the transverse angle may vary between 60.6° and 84.1° (mean 69.4°), and that reduction of this angle may cause various symptoms. Andrei et al. [2] reported the mean transverse angle to be 66.74°. İlgüy et al. [14] stated that the mean size of this angle was 66.4° and also proposed that narrowing of this angle may cause pressure on arteria carotis externa due to its close proximity to the SHC. They reported the mean size of the sagittal angle, also called the anteroposterior angle, to be 25.66° for the right side and 25.46° for the left side. They suggested that a change in this angle may cause compression of the IX–XIIth cranial nerves, arteria carotis interna, or vena jugularis interna, depending on the posterior position of the SHC. The mean SHC thickness was 4.8 mm in their study and there was a correlation between SHC thickness and anteroposterior angle. Büyük et al. [6] observed a positive correlation between the anterior sagittal angle and SHC length; larger sagittal angle was associated with a longer SHC. The mean SHC thickness was 3.97 mm in females and 4.44 mm in males in their study.

Based on the results of the present study, the mean transverse angle was 70.39 ± 4.59° on the right side and 71.79 ± 4.99° on the left side. Mean sagittal angle was 27.43 ± 6.75° on the right side and 27.70 ± 6.75° on the left. Mean SHL thickness was found to be 3.31 mm on the right and 2.93 mm on the left (Table 2). These transverse and sagittal angle sizes support previous studies, whereas SHC thickness was lower in our study [6, 14]. However, it should be kept in mind that these values may vary between individuals and populations, and may be influenced by age and gender distribution.

Due to the interconnected nature of the craniofacial structures, a structural change in one of them is expected to lead to changes in the other structures as well. Os temporale is at the centre of the dynamic craniofacial complex and interacts with the lobus temporalis of telencephalon, the central face, and the mandible during growth and development [5, 8]. Anchored on the SP extending from the posterior surface of os temporale, the SHL and musculus stylohyoideus extend to os hyoideum. Kumar Jena and Duggal [19] have reported that os hyoideum might be positioned more posteriorly in patients with a vertical growth model, while Deljo et al. [9] proposed a correlation between the position of os hyoideum and the position of the cranial base/maxilla. Graber [12] observed inferoposterior movement of os hyoideum consistent with the backward and downward repositioning of the mandible after chin-cup therapy in 30 individuals with mandibular prognatism. Previous studies on hyoid bone position have suggested a possible correlation between this bone and maxillomandibular morphology; however, relationships with the temporal bone and the SHC have been disregarded [9, 12, 19]. Therefore, the primary aim of our study was to evaluate the association between SHC morphology and maxillomandibular position.

In the present study, no significant differences emerged when SHC morphology parameters were analysed according to ANB angle (reflecting sagittal maxillomandibular relationship) or GoGn/SN angle (reflecting vertical mandibular position) (Tables 4 and 6). Therefore, we can conclude that maxillomandibular relationship and mandibular rotation are not directly associated with the SHC. However, although the ANB angle is a measure of the interrelation of the mandible and maxilla, it does not allow separate analysis of maxillary or mandibular position/length. Though it is believed that mandibular rotation generally influences the vertical facial dimensions, there may be inconsistency between vertical dimensions and mandibular rotation in some cases [15]. In fact, the length of anterior skull base (S-N) increases from childhood to adulthood [31]. The measurements used in our study may be affected by nasion position and growth. In addition, it has been claimed in previous studies that SHC calcification and dimensions may change with age [10, 25]. Therefore, a more detailed analysis of the maxillary and mandibular position/length and the vertical dimensions for different age groups may yield more accurate results.

Analysis within the skeletal malocclusion groups for gender differences showed that males with class III malocclusion have longer SHC on both the right and the left sides (Table 5). Previous studies have also demonstrated that SHC length may be longer in males [6, 14]. However, it is interesting that this difference was observed only in class III individuals in our study. In a study including 1094 individuals with class III malocclusion, Baccetti et al. [3] reported pronounced sexual dimorphism, especially after the age of 13, with males showing relatively longer mandibular, maxillary, and vertical dimensions compared to females. Therefore, we believe that the difference observed in class III individuals in our study is largely attributable to longer mandibular length in males, as well as to the more forward position of the hyoid bone, and muscle elongation consistent with the functional matrix theory. However, as this study did not include a separate analysis of mandibular length, we cannot reach a definitive conclusion.

CONCLUSIONS

Awareness of potential anatomic variations in SHC morphology is important both in the diagnostic phase and in the success of surgical procedures performed in the region. Three-dimensional CBCT images enable a detailed evaluation of the SHC. The results of this study revealed no significant associations between the maxillomandibular relationship, mandibular rotation, and the SHC. However, among the subjects with skeletal class III malocclusion, SHC was longer in men than in women. Further research with larger study populations and more angular/linear craniofacial measurements are needed to obtain more complete and accurate information on this topic.

REFERENCES

1. Alpoz E, Akar GC, Celik S, et al. Prevalence and pattern of stylohyoid chain complex patterns detected by panoramic radiographs among Turkish population. Surg Radiol Anat. 2014; 36(1): 39–46, doi: 10.1007/s00276-013-1137-x, indexed in Pubmed: 23689822.
2. Andrei F, Motoc AG, Didilescu AC, et al. A 3D cone beam computed tomography study of the styloid process of the temporal bone. Folia Morphol. 2013; 72(1): 29–35, doi: 10.5603/fm.2013.0005, indexed in Pubmed: 23749708.
3. Baccetti T, Reyes BC, McNamara JA. Gender differences in Class III malocclusion. Angle Orthod. 2005; 75(4): 510–520, doi: 10.1043/0003-3219(2005)75[510:GDICIM]2.0.CO;2, indexed in Pubmed: 16097218.
4. Başekim CC, Mutlu H, Güngör A, et al. Evaluation of styloid process by three-dimensional computed tomography. Eur Radiol. 2005; 15(1): 134–139, doi: 10.1007/s00330-004-2354-9, indexed in Pubmed: 15221266.
5. Bastir M, Rosas A. Correlated variation between the lateral basicranium and the face: a geometric morphometric study in different human groups. Arch Oral Biol. 2006; 51(9): 814–824, doi: 10.1016/j.archoralbio.2006.03.009, indexed in Pubmed: 16681992.
6. Buyuk C, Gunduz K, Avsever H. Morphological assessment of the stylohyoid complex variations with cone beam computed tomography in a Turkish population. Folia Morphol. 2018; 77(1): 79–89, doi: 10.5603/FM.a2017.0061, indexed in Pubmed: 28653301.
7. Colby CC, Del Gaudio JM. Stylohyoid complex syndrome: a new diagnostic classification. Arch Otolaryngol Head Neck Surg. 2011; 137(3): 248–252, doi: 10.1001/archoto.2011.25, indexed in Pubmed: 21422308.
8. Costa HN, Slavicek R, Sato S. A computerized tomography study of the morphological interrelationship between the temporal bones and the craniofacial complex. J Anat. 2012; 220(6): 544–554, doi: 10.1111/j.1469-7580.2012.01499.x, indexed in Pubmed: 22458595.
9. Deljo E, Filipovic M, Babacic R, et al. Correlation analysis of the hyoid bone position in relation to the cranial base, mandible and cervical part of vertebra with particular reference to bimaxillary relations / teleroentgenogram analysis. Acta Inform Med. 2012; 20(1): 25–31, doi: 10.5455/aim.2012.20.25-31, indexed in Pubmed: 23322951.
10. Donmez M, Okumus O, Pekiner FN. Cone beam computed tomographic evaluation of styloid process: A retrospective study of 1000 patients. Eur J Dent. 2017; 11(2): 210–215, doi: 10.4103/ejd.ejd_56_17, indexed in Pubmed: 28729795.
11. Eagle WW. Elongated styloid processes: report of two cases. Arch Otolaryngol - Head and Neck Surgery. 1937; 25(5): 584–587, doi: 10.1001/archotol.1937.00650010656008.
12. Graber LW. Hyoid changes following orthopedic treatment of mandibular prognathism. Angle Orthod. 1978; 48(1): 33–38, doi: 10.1043/0003-3219(1978)048<0033:HCFOTO>2.0.CO;2, indexed in Pubmed: 272129.
13. Haroun HWS. Morphometric and radiological evaluation of the stylohyoid complex in man. Ann Int Med Den Res. 2015; 1(2): 49–52.
14. Ilgüy D, Ilgüy M, Fişekçioğlu E, et al. Assessment of the stylohyoid complex with cone beam computed tomography. Iran J Radiol. 2012; 10(1): 21–26, doi: 10.5812/iranjradiol.4891, indexed in Pubmed: 23599709.
15. Isaacson JR, Isaacson RJ, Speidel TM, et al. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthod. 1971; 41(3): 219–229, doi: 10.1043/0003-3219(1971)041<0219:EVIVFG>2.0.CO;2, indexed in Pubmed: 5283670.
16. Ishii N, Deguchi T, Hunt NP. Morphological differences in the craniofacial structure between Japanese and Caucasian girls with Class II Division 1 malocclusions. Eur J Orthod. 2002; 24(1): 61–67, doi: 10.1093/ejo/24.1.61, indexed in Pubmed: 11887380.
17. Ishii N, Deguchi T, Hunt NP. Craniofacial differences between Japanese and British Caucasian females with a skeletal Class III malocclusion. Eur J Orthod. 2002; 24(5): 493–499, doi: 10.1093/ejo/24.5.493, indexed in Pubmed: 12407945.
18. Jung T, Tschernitschek H, Hippen H, et al. Elongated styloid process: when is it really elongated? Dentomaxillofac Radiol. 2004; 33(2): 119–124, doi: 10.1259/dmfr/13491574, indexed in Pubmed: 15314005.
19. Kumar Jena A, Duggal R. Hyoid bone position in subjects with different vertical jaw dysplasias. Angle Orthod. 2011; 81(1): 81–85, doi: 10.2319/092208-491.1, indexed in Pubmed: 20936958.
20. Mahdian M, Moghaddam EJ, Alzahrani A, et al. Calcification of the stylohyoid ligament in panoramic radiography and cone beam computed tomography among patients referred for dental implant treatment planning. Implant Dent. 2014; 23(4): 508–513, doi: 10.1097/ID.0000000000000125, indexed in Pubmed: 25033348.
21. Moss ML. The functional matrix hypothesis revisited. 1. The role of mechanotransduction. Am J Orthod Dentofacial Orthop. 1997; 112(1): 8–11, doi: 10.1016/s0889-5406(97)70267-1, indexed in Pubmed: 9228835.
22. Carroll M. Calcification in the stylohyoid ligament. Oral Surgery, Oral Medicine, Oral Pathology. 1984; 58(5): 617–621, doi: 10.1016/0030-4220(84)90089-6.
23. Okabe S, Morimoto Y, Ansai T, et al. Clinical significance and variation of the advanced calcified stylohyoid complex detected by panoramic radiographs among 80-year-old subjects. Dentomaxillofac Radiol. 2006; 35(3): 191–199, doi: 10.1259/dmfr/12056500, indexed in Pubmed: 16618854.
24. Onbas O, Kantarci M, Murat Karasen R, et al. Angulation, length, and morphology of the styloid process of the temporal bone analyzed by multidetector computed tomography. Acta Radiol. 2005; 46(8): 881–886, doi: 10.1080/02841850500335085, indexed in Pubmed: 16392614.
25. Öztaş B, Orhan K. Investigation of the incidence of stylohyoid ligament calcifications with panoramic radiographs. J Investig Clin Dent. 2012; 3(1): 30–35, doi: 10.1111/j.2041-1626.2011.00081.x, indexed in Pubmed: 22298518.
26. Proffit WR, Sarver DM, Ackerman JL. Orthodontic diagnosis: the problem oriented approach. In: Fields HW (ed.). Contempporary Orthodontics Mosby, St. Louis 2013: 181–203.
27. Sandev S, Sokler K. Styloid process syndrome. Acta Stomat Croat. 2000; 34(4): 451–456.
28. Sathler R, Pinzan A, Fernandes TM, et al. Comparative study of dental cephalometric patterns of Japanese-Brazilian, Caucasian and Mongoloid patients. Dental Press J Orthod. 2014; 19(4): 50–57, doi: 10.1590/2176-9451.19.4.050-057.oar, indexed in Pubmed: 25279521.
29. Steiner C. Cephalometrics for you and me. Am J Orthod. 1953; 39(10): 729–755, doi: 10.1016/0002-9416(53)90082-7.
30. Steiner CC. Cephalometrics in clinical practice. Angle Orthod. 1959; 29(1): 8–29.
31. Thilander B, Persson M, Adolfsson U. Roentgen-cephalometric standards for a Swedish population. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod. 2005; 27(4): 370–389, doi: 10.1093/ejo/cji033, indexed in Pubmed: 16043474.