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Evaluation of the Sella Morphology in Chiari Malformation Type I

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ABSTRACT

AIM: To investigate the morphology of sella turcica (ST) in Chiari malformation type I (CM-I) using computed tomography.

MATERIAL and METHODS: The size and shape of ST were examined using the radiological images of 32 CM-I patients (21 female/11 male, mean age: 26.09 ± 15.39 years), and 32 normal participants (19 female/13 male, mean age: 28.56 ± 19.37 years).

RESULTS: The height, diameter, width, and length of ST were similar in CM-I and control groups (p>0.05). According to the Axelsson classification, the ST shape in CM-I was identified as normal in 16 patients (50%), oblique anterior wall in 2 patients (6.25%), irregularity in 6 patients (18.75%), and pyramidal shape of the dorsum sellae in 8 patients (25%). In controls, the ST shape was identified as normal in 18 patients (56.25%), oblique anterior wall in 4 patients (12.50%), irregularity in 2 patients (6.25%), and pyramidal shape of the dorsum sellae in 8 patients (25%). According to the Camp classification, the ST shape in CM-I was identified as oval in 6 patients (18.80%), round in 21 patients (65.60%), and flattened in 5 patients (15.60%). In controls, the ST shape was identified as oval in 19 subjects (59.40%), round in 10 patients (31.30%), and flattened in 3 patients (9.40%).

CONCLUSION: The size of ST in patients with CM-I was similar to that in healthy partcipants. The only difference in ST morphology was that patients with CM-I had more round-shaped sella, whereas normal subjects had more oval-shaped sella.

KEYWORDS: Sella turcica, Sella morphology, Chiari Malformation Type I, Tuberculum Sellae, Dorsum Sellae

ABBREVIATIONS: ST: Sella turcica, **DS:** Dorsum sellae, **TS:** Tuberculum sellae, **CM-I:** Chiari malformation type I, **CM-II:** Chiari malformation type II, **MRI:** Magnetic resonance imaging, **CT:** Computed tomography, **STD:** Diameter of sella turcica, **STW:** Width of sella turcica, **STL:** Length of sella turcica, **STA:** Anterior height of sella turcica, **STM:** Middle height of sella turcica, **STP:** Posterior height of sella turcica.

INTRODUCTION

Sella turcica (ST), defined as a depression on the superior part of the sphenoid bone body, has three compartments, dorsum sellae (DS), tuberculum sellae (TS), and hypophyseal fossa (36). The morphology of ST and its components are considerably important for clinicians because of its close relationship with numerous anatomical structures such as the pituitary gland, cavernous sinus, internal carotid artery, optic chiasm, sphenoid sinus, oculomotor nerve, abducens nerve, and trochlear nerve (9,10,16,22). To prevent idiopathic damage to these structures during procedures such as en-

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doscopic pituitary surgery, surgical teams must consider the anatomical variations of ST (9,10,13,16,22,28,33). Conversely, the sella morphology may be affected by some pathologies or malformations (e.g., Sheehan's syndrome, Nelson syndrome, empty sella syndrome, Down syndrome, cleft lip/palate, acromegaly, gigantism, mucocele, and meningioma) (25,31,55). In this context, detailed information related to ST may be helpful for surgeons to understand the complex anatomy of the sellar region.

Patel et al. encountered an enlarged pituitary gland on the radiological images of some subjects with Chiari malformation type II (CM-II) (43). Subsequently, they conducted a systematic study to investigate sella morphology using the magnetic resonance imaging (MRI) images of 21 participants and observed taller pituitary gland (with no pathology), longer TS, shorter DS, and shallow ST in patients with CM-II than in controls. The pituitary gland of CM-II patients may be slightly taller on MRI images because of a shallow ST, which may result in the normal gland being incorrectly interpreted as enlarged in such patients (43). Conversely, patients with Chiari malformation type I (CM-I) have 38% greater sphenoid sinus volume than controls (39). Furthermore, such patients had 27% smaller ST area than normal subjects (39). Consistent with this knowledge, we consider that the sella morphology is affected by CM-I. Due to the greater sphenoid sinus volume and shorter clivus, we predicted a shallow ST in patients with CM-I compared with that in healthy participants. We conducted this computed tomography (CT) investigation to determine whether the sella morphology is altered in patients with CM-I compared with that in normal participants.

MATERIAL and METHODS

Study Population

This retrospective CT study was approved by the Clinical Research Ethics Committee (confirmation no. 2023/109). Subjects' folders (including the following data: hospital admission/discharge dates, treatment procedures, diagnosis, complaints, cranial CT and MRI images, age at presentation, and sex) were retrospectively reviewed. CM-I was diagnosed if the cerebellar tonsil herniated more than 5 mm downward from the foramen magnum in a patient without a history of meningomyelocele. Consistent with the criteria (Table I), the following two study populations were formed: a) controls (an age-sex-matched set) and b) patients with CM-I.

CT Protocol

CT images of patients' skull bases were obtained using a 64-row multidetector scanner (Aquillion 64, matrix: 512 × 512, field of view: 240 mm, pixel size: 0.46 mm, 0.5-mm-thick slices, 230 mA, 120 kV, 0.3-mm interval; Toshiba Medical Systems, Tokyo, Japan). By transferring the data to a workstation, the raw data were converted into three-dimensional (3D) images and later reformatted in different planes (sagittal, coronal, and axial).

Measured Parameters

The following parameters were selected for determining the sella morphology: diameter (STD), width (STW), length (STL), anterior height (STA), middle height (STM), and posterior height (STP) of ST. The explanations of these parameters are presented in Table II (17,19,54). The images of CM-I and control groups were brought to the neutral position during the measurements. Reference points were determined on the coronal, sagittal, and axial planes to standardize the images. Two lines were determined for the standardization of measurements, viz., a sagittal line passing through the crista galli and anterior nasal spine on the coronal plane and a sagittal line passing through the internal occipital protuberance and anterior nasal spine on the axial plane. All measurements were performed on midsagittal images coinciding with these lines (Figure 1).

Classification of ST Shape

Previous studies used different classifications to evaluate ST shape (5,11). According to the classification described by Axelsson et al. (5), the ST shape was identified as follows: Type 1: normal ST; Type 2: oblique anterior wall; Type 3: double contour of the floor; Type 4: irregularity (notching); Type 5: ST bridge; and Type 6: pyramidal shape of DS. Furthermore, according to the classification of Camp (11), the ST shape was identified as follows: oval, round, and flattened. We identified our study participants based on these classifications.

Statistical Analysis

Statistical analyses were conducted using SPSS for the Windows version 22.0 package program (IBM, Armonk, NY). Normality for STD, STW, STL, STA, STM, and STP was evaluated using the Shapiro–Wilk test. CM-I/controls or male/female comparison was performed using the independent samples t-test. Dispersion of ST shapes in controls and patients with CM-I was investigated using the chi-square test. A p value <0.05 was considered statistically significant.

RESULTS

We examined the radiological images of 32 (21 women/11 men) patients aged 26.09 ± 15.39 years (range: 6–63 years) admitted to the hospital between 2010 and 2022. We also examined the radiological images of 32 (19 women/13 men) healthy subjects aged 28.56 ± 19.37 years (range: 6–67 years) admitted to the hospital in 2020 due to different complaints (falling from a height, etc.). We observed the following findings:

- All morphometric parameters were similar in CM-I patients and controls (p>0.05) (Table III).
- In both groups, the measured parameters in men were similar to those in women (p>0.05), except for the STP of controls (which was greater in women than men, p=0.001) (Table IV).
- According to the Axelsson classification, the ST shape in CM-I was identified as Type 1 in 16 patients (50%), Type 2 in 2 patients (6.25%), Type 4 in 6 patients (18.75%), and Type 6 in 8 patients (25%). In controls, the ST shape was identified as Type 1 in 18 participants (56.25%), Type 2 in 4 participants (12.50%), Type 4 in 2 subjects (6.25%), and

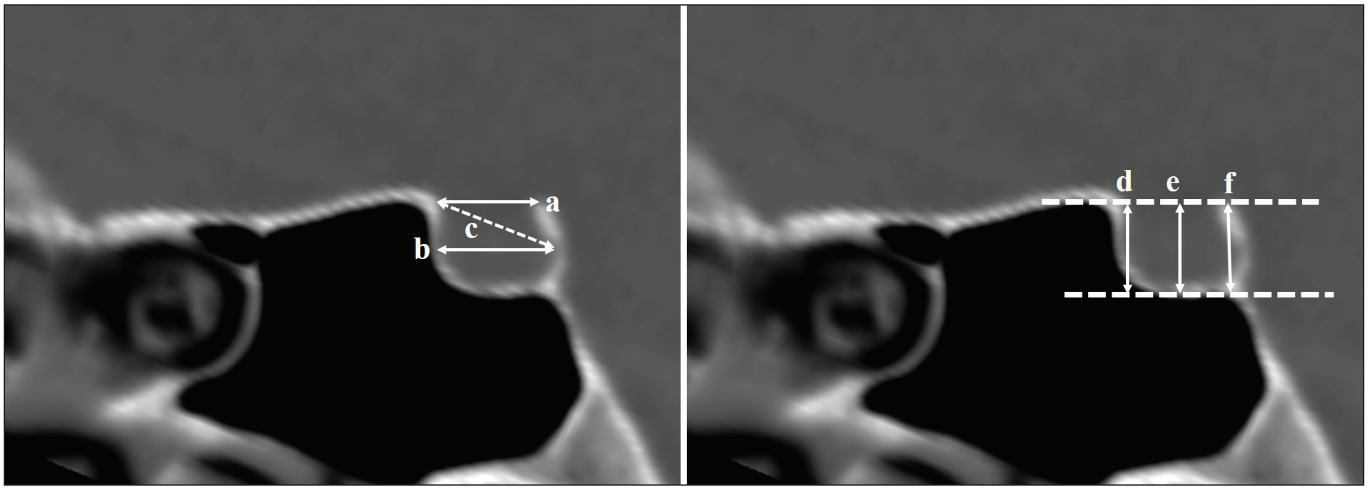

Figure 1: Photographs showing the measured parameters. **a:** STL, **b:** STW, **c:** STD (the dashed line), **d:** STA, **e:** STM, and **f:** STP.

Table I: The Inclusion and Exclusion Criteria for the Study Populations

Criteria	CM-I	Control group
Inclusion criteria	Patients with CM-I	Patients without malformations (syndromic or genetic)
	Patients without a history of surgical intervention around ST	Patients without fractures, infections, tumors
	Patients with good quality CT images	Patients without a history of surgical intervention around ST
		Patients without a history of medical treatment related to ST
		Patients with good quality CT images
Exclusion criteria	Patients with the other types of Chiari malformation	Patients with malformations (syndromic or genetic)
	Patients with a history of surgical intervention around ST	Patients with fractures, infections, tumors
	Patients with low quality CT images	Patients with a history of surgical intervention around ST
		Patients with a history of medical treatment related to ST
		Patients with low quality CT images

Table II: Definitions of the Parameters

Parameters	Descriptions
STL	The distance between TS and DS points
STD	The distance measured from TS to the backmost point in the interior surface of the posterior wall of the pituitary fossa
STA	The vertical distance measured from TS through ST base to the Frankfort horizontal plane
STM	The vertical distance measured from the midpoint between TS and DS to the Frankfort horizontal plane.
STP	The vertical distance measured from DS through ST base to the Frankfort horizontal plane
STW	The longest antero-posterior length measured parallelly from the most anterior and posterior points of ST to the Frankfort horizontal plane

Type 6 in 8 subjects (25%). Types 3 and 5 were not observed in both groups (Table V) (Figure 2). The dispersion ratio of ST shapes in patients with CM-I and controls is shown in Table V, which confirms that the Axelsson classification was not affected by CM-I (p=0.426).

- According to the Camp classification, the ST shape in CM-I was identified as oval in 6 patients (18.80%), round in 21 patients (65.60%), and flattened in 5 patients (15.60%). In controls, the ST shape was identified as oval in 19 participants (59.40%), round in 10 participants (31.30%), and flattened in 3 subjects (9.40%) (Table VI) (Figure 3). The dispersion ratio of ST shapes in CM-I patients and controls is presented in Table VI, which confirms that the Camp classification was affected by CM-I (p = 0.004).

Table III: Comparison of CM-I, and Controls

Parameters	CM-I (n=32)	Control (n=32)	p-value
STL (mm)	9.19 ± 1.76	9.26 ± 1.79	0.889
STD (mm)	10.90 ± 1.65	11.54 ± 2.05	0.176
STA (mm)	7.86 ± 1.87	7.77 ± 1.51	0.837
STM (mm)	8.10 ± 1.89	8.37 ± 1.34	0.514
STP (mm)	8.24 ± 2.21	9.03 ± 1.55	0.105
STW (mm)	9.41 ± 2.23	9.03 ± 1.94	0.463

***N:** Numbers of sides.*

DISCUSSION

A detailed understanding of ST anatomy is considerably important for clinicians during radiological evaluations of the craniofacial and neurocranial complex (31). An enlarged ST may be associated with empty sella syndrome, acromegaly, gigantism, prolactinoma, primary hypothyroidism, meningioma, mucocele, and adenomas; moreover, the less common small ST may be associated with Sheehan's syndrome and primary hypopituitarism (31). For instance, Axelsson et al. observed smaller STD in subjects with Williams syndrome than in normal subjects (4). Yalcin observed smaller STD in patients with cleft palate/lip (10.04 ± 1.40 mm) than in control subjects (11.18 ± 1.80 mm, p=0.008) (55). Korayem and AlKofide reported greater STD (13 ± 1.60 mm) and STM (8.90 ± 1.10 mm) in patients with Down syndrome than the STD (12.30 ± 1.50 mm) and STM (7.80 ± 1.40 mm) of control subjects (25). Mølsted et al. stated that individuals with velocardiofacial syndrome had larger deviations in ST morphology (especially, deviations in the posterior part of DS such as the high incidence of Type 6) (32). Kjaer et al. reported that the contour of the anterior wall of ST followed an anteroposterior direction in subjects with myelomeningocele, in contrast to following a craniocaudal orientation in healthy subjects; thus, this situation resulted in a wider and shallow sella appearance in patients with myelomeningocele (24). Some authors suggest that individuals with an abnormal decrease or enlargement in ST size during radiological examinations can be referred to the endocrinology or neurology clinic, which may consequently help in early detection of a pathology or malformation without any symptoms (8).

Table IV: Sex and Side Comparisons for CM-I, and Controls

	CM-I			Control		
Parameters	**Female (n=21)**	**Male (n=11)**	**p-value**	**Female (n=19)**	**Male (n=13)**	**p-value**
STL (mm)	9.38 ± 1.84	8.84 ± 1.60	0.417	9.23 ± 1.85	9.29 ± 1.76	0.927
STD (mm)	11.06 ± 1.62	10.60 ± 1.75	0.465	11.55 ± 2.01	11.52 ± 2.18	0.970
STA (mm)	7.90 ± 1.96	7.76 ± 1.78	0.844	7.87 ± 1.29	7.62 ± 1.84	0.658
STM (mm)	8.28 ± 2.01	7.74 ± 1.68	0.455	8.72 ± 1.22	7.85 ± 1.39	0.071
STP (mm)	8.47 ± 2.34	7.81 ± 1.99	0.431	9.73 ± 1.38	8.02 ± 1.21	**0.001**
STW (mm)	9.70 ± 1.99	8.86 ± 2.64	0.319	9.38 ± 2.19	8.51 ± 1.42	0.220

***N:** Numbers of sides.*

Table V: Distribution of ST Shapes Defined by Axelsson et al. (5) in CM-I, and Controls

Types	CM-I	Control	Total	p-value
Type 1	16 (50%)	18 (56.25%)	34	0.426
Type 2	2 (6.25%)	4 (12.50%)	6	
Type 4	6 (18.75%)	2 (6.25%)	8	
Type 6	8 (25%)	8 (25%)	16	
Total	32	32	64	

***Type 1:** Normal sella turcica, **Type 2:** Oblique anterior wall, **Type 4:** Irregularity (notching), **Type 6:** pyramidal shape of the dorsum sellae.*

Table VI: Distribution of ST Shapes Defined by Camp (11) in CM-I, and Controls

Types	CM-I	Control	Total	p-value
Oval	6 (18.80%)	19 (59.40%)	25	0.004
Round	21 (65.60%)	10 (31.30%)	31	
Flattened	5 (15.60%)	3 (9.40%)	8	
Total	32	32	64	

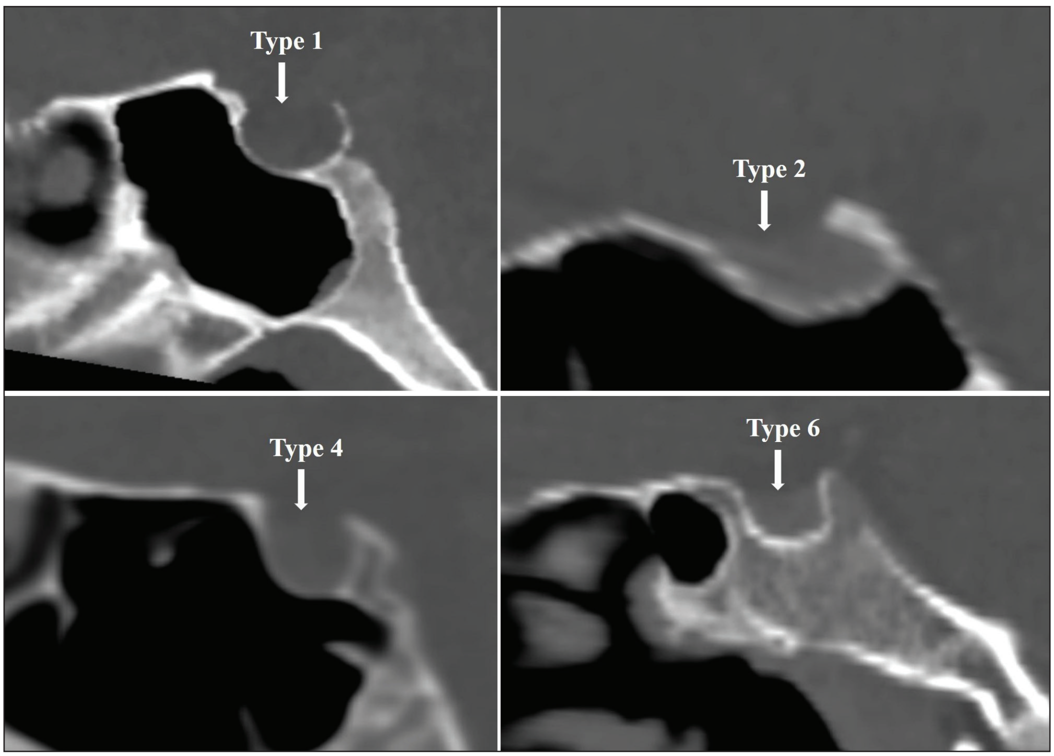

Figure 2: Photographs showing ST shapes reported by Axelsson et al. (5). Type 1: normal; Type 2: oblique anterior wall; Type 4: irregularity (notching); and Type 6: pyramidal shape of the dorsum sellae.

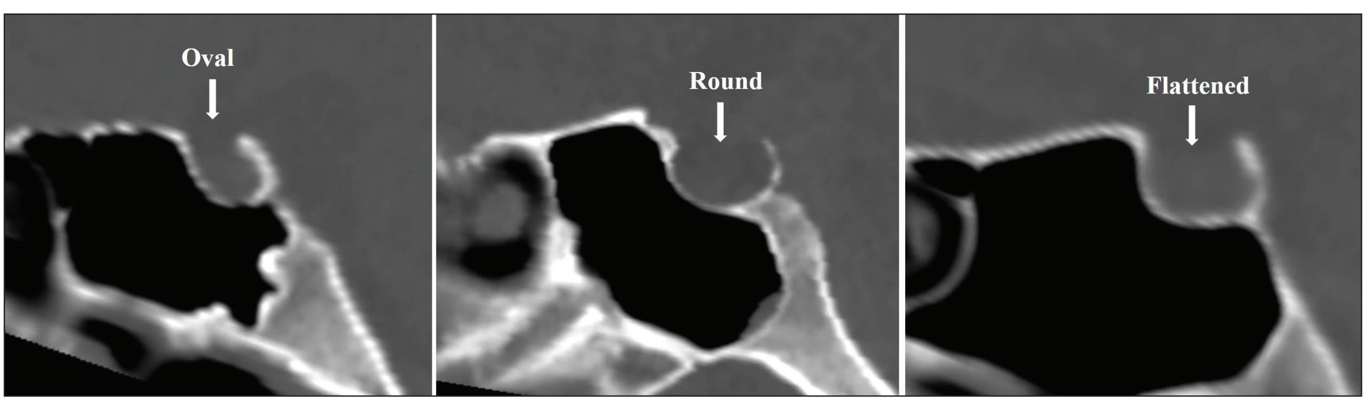

Figure 3: Photographs showing ST shapes reported by Camp (11) (oval, round, and flattened ST).

Therefore, our findings may be useful for neuroradiologists to understand whether a difference exists in sella morphology between healthy subjects and CM-I patients.

CM-I is described as the downward herniation of the cerebellar tonsil through the foramen magnum (21). In the literature, its prevalence is reported as 0.24%–3.6% (21). Its primary cause is presumably deviations in the development of the occipital somite originating from the paraxial mesoderm (6). This condition generally affects the posterior fossa and its bony components (e.g., 23% smaller posterior fossa volume in patients with CM-I) (6,46). The smaller fossa might result in hindbrain overcrowding, causing an extremely diverse range of symptoms (e.g., vertigo, hearing loss, hoarseness, pain, facial numbness, and gait instability) in patients with CM-I (6,38,46,50,52,53). Some authors mentioned that a mesodermal defect probably results in important alterations in patients with CM-I, not only in their posterior fossa but also in their entire skull base (39,47). For instance, Sgouros et al. reported a longer anterior fossa in pediatric subjects with CM-I than in controls (47). Furthermore, Nwotchouang et al. observed that the sphenoid sinus volume in healthy participants (6.7 ± 1.9 cm^3) was 38% smaller than that in CM-I patients (9.3 ± 3.0 cm^3, $p<0.001$) (39). We believe that these alterations affect the sizes and locations of all structures around the sellar area, including the ST. Patel et al. reported that a shallow ST in CM-II patients may result in an erroneous interpretation, such as pituitary enlargement on MRI, because normal glands appear slightly taller than ST (43). Therefore, a detailed dataset (including size and shape evaluations) concerning ST in CM-I may be helpful for clinicians to avoid erroneous interpretations, such as pituitary enlargement on MRI.

In the CM-I group, the STL, STD, STA, STM, STP, and STW were 9.19 ± 1.76 mm, 10.90 ± 1.65 mm, 7.86 ± 1.87 mm, 8.10 ± 1.89 mm, 8.24 ± 2.21 mm, and 9.41 ± 2.23 mm, respectively. In controls, STL, STD, STA, STM, STP and STW were measured as 9.26 ± 1.79 mm, 11.54 ± 2.05 mm, 7.77 ± 1.51 mm, 8.37 ± 1.34 mm, 9.03 ± 1.55 mm, and 9.03 ± 1.94 mm, respectively. All the morphometric data in CM-I patients were similar to those in controls ($p>0.05$). Therefore, our data showed that ST size was not affected by CM-I. Unlike the study of Patel et al. (who observed shallow sella in CM-II patients), we did not observe any difference in the sella dimension between the control and CM-I groups (43). The mean values for the measured parameters in CM-I patients and controls in our study were compatible with those of previous studies (Table VII) (1-3,7, 12,14,15,17-20,23,25,27,29,30,34,35,37,40,45,48,49,51,54-57), wherein the average range was 7–11.40 mm for STL, 9.20–14 mm for STD, 3.86–8.09 mm for STA, 6.32–9.90 mm for STM, and 8.21–10.96 mm for STW in healthy subjects. Nevertheless, the mean STP values in both groups were greater than the average values (3.95–7.48 mm) reported in the literature (Table VII). The average values related to these six parameters in the previous studies (Table VII) showed a rather large range. The reasons for the discrepancies between the morphometric values of previous studies may be as follows: imaging methods, selection of divergent landmarks, and demographic differences (sex, age, region, etc.) (55).

In the CM-I group, four different shapes reported by Axelsson et al. were identified as follows: Type 1 (16 patients, 50%) > 6 (8 patients, 25%) > 4 (6 patients, 18.75%) > 2 (2 patients, 6.25%) (5). Similarly, in the control group, four different shapes were identified as follows: Type 1 (18 patients, 56.25%) > 6 (8 patients, 25%) > 2 (4 patients, 12.50%) > 4 (2 patients, 6.25%). Our data demonstrated that the ST shape was not affected by CM-I ($p=0.426$), considering the classification of Axelsson et al. (5). In the literature (Table VIII) (1,5,7,19,20,23,26,27,30,37, 40,44,45,48,55,58), the frequency range of ST shapes was 27.3%–76.15% for Type 1, 1.9%–18.86% for Type 2, 0%–22.9% for Type 3, 0%–39.7% for Type 4, 0%–16% for Type 5, and 0%–15.5% for Type 6 in healthy subjects. In our study, Types 3 and 5 were not observed in both groups. However, the shape of ST was classified by Camp into three types, viz., oval, round, and flattened (11). In CM-I patients, the distribution ranking of ST shapes was round (21 patients, 65.60%) > oval (6 patients, 18.80%) > flattened (5 patients, 15.60%). In controls, the distribution ranking of ST shapes was oval (19 subjects, 59.40%) > round (10 subjects, 31.30%) > flattened (3 patients, 9.40%). CM-I patients had more round-shaped ST, whereas normal subjects had more oval-shaped ST. Based on the Camp classification (11), our findings demonstrated that the ST shape was affected by CM-I ($p = 0.004$). In the literature (Table IX) (19, 55-57), the frequency range of ST shapes was 14.1%–48.1% for oval-shaped ST, 23.4%–71.8% for round-shaped ST, and 11.8%–28.3% for flattened-shaped ST in healthy subjects. These rates reveal that the shape definitions are quite variable. The primary reasons for the variations between studies may be as follows: demographic differences (sex, age, region, etc.), imaging methods, selection of divergent landmarks, and imperfect techniques (55).

Recent examinations conducted on the anterior part of the skull base revealed that CM-I patients had a shorter anterior clinoid process, longer optic strut, more anteriorly located optic strut, wide-angled anterior clinoid process, and greater sulcal angle (angle between the prechiasmatic sulcus and sphenoidal yoke) than controls (41,42). Nwotchouang et al. observed that the ST area in patients with CM-I (69.7 ± 22.1 mm^2) was 27% smaller than that in normal subjects (95.1 ± 23.8 mm^2, $p<0.001$) (39). However, we observed that patients with CM-I had only more round-shaped ST than controls. These findings confirm that the entire skull base of patients with CM-I has significant differences from that of normal participants.

There are some limitations in this study. First, our sample size of patients with CM-I was small; therefore, further studies focusing on larger sample groups may contribute to the understanding of the anatomy of the sellar region in CM-I patients. Similarly, the sample size of controls was small; hence, a larger sample size for controls would yield more reliable comparative data. Second, we measured the parameters (diameter, height, width, etc.) commonly used in studies focusing on ST anatomy in the literature; therefore, future studies incorporating additional parameters (e.g., area and volume) may provide a more precise understanding of the sella morphology in patients with CM-I.

Table VII: Morphometric Data Related to the Sella Morphology in the Literature

Study	Region	Samples	Age	N	Methods	STL (mm)	STD (mm)	STA (mm)	STM (mm)	STP (mm)	STW (mm)
Islam et al. (19)	Bangladesh	HS (Male)	18-65 y	108	CT	8.63 ± 1.84	9.90 ± 1.51	7.21 ± 1.23	6.61 ± 1.17	6.93 ± 1.21	8.42 ± 1.30
		HS (Female)	18-65 y	58	CT	8.21 ± 1.32	9.78 ± 1.14	6.97 ± 1.04	6.48 ± 0.80	6.72 ± 0.85	8.64 ± 1.24
Ize-Iyamu (20)	Nigeria	HS	7-32 y	106	LCR	10.20 ± 1.89	9.20 ± 1.86	-	7.04 ± 2.16	-	-
Korayem and AlKofide (25)	Saudi Arabia	Down syndrome	12-22 y	60	LCR	10.20 ± 2.00	13.00 ± 1.60	-	8.90 ± 1.10	-	-
		Control	12-22 y	60	LCR	10.10 ± 1.70	12.30 ± 1.50	-	7.80 ± 1.40	-	-
Baidas et al. (7)	Saudi Arabia	Malposed Canine	12-25 y	62	LCR	7.19 ± 2.17	10.59 ± 1.81	-	8.02 ± 1.36	-	-
		Control	12-25 y	54	LCR	9.18 ± 1.48	11.35 ± 1.44	-	8.92 ± 1.55	-	-
Kiran et al. (23)	India	HS (Male)	10-61 y	130	LCR	-	11.74 ± 1.73	-	7.68 ± 1.60	-	-
		HS (Female)	10-61 y	130	LCR	-	12.25 ± 1.50	-	8.08 ± 1.49	-	-
Kumar and Govindraju (27)	India	HS (Male)	6-40 y	123	LCR	8.10 ± 1.86	10.42 ± 1.52	-	6.90 ± 1.17	-	-
		HS (Female)	6-40 y	188	LCR	7.98 ± 1.61	10.43 ± 1.29	-	7.04 ± 1.21	-	-
Shah et al. (48)	Pakistan	HS (Male)	>15 y	90	LCR	11.40 ± 1.45	13.90 ± 2.11	-	9.80 ± 1.30	-	-
		HS (Female)	>15 y	90	LCR	11.20 ± 2.40	11.80 ± 1.90	-	9.90 ± 2.20	-	-
Nagaraj et al. (37)	India	HS	8-30 y	200	LCR	9.52 ± 1.76	11.83 ± 1.85	-	8.21 ± 1.48	-	-
Andredaki et al. (3)	Greece	HS (Male)	6-17 y	91	LCR	7.10 ± 1.60	-	6.70 ± 1.00	6.60 ± 0.80	6.60 ± 1.00	8.90 ± 1.20
		HS (Female)	6-17 y	93	LCR	7.00 ± 1.70	-	7.20 ± 1.30	6.80 ± 1.00	6.50 ± 1.00	9.10 ± 1.20
Taner et al. (51)	Turkey	HS	18-45 y	80	CBCT	10.00 ± 1.70	12.20 ± 2.00	-	9.00 ± 1.50	-	-
Alkofide (1)	Saudi Arabia	HS (Male)	10-26 y	90	LCR	11.00 ± 2.63	13.90 ± 2.10	-	9.10 ± 1.21	-	-
		HS (Female)	10-26 y	90	LCR	10.70 ± 2.01	14.00 ± 1.78	-	9.10 ± 1.44	-	-
Yalcin (55)	Turkey	Cleft lip/palate	7-20	68	CBCT	8.75 ± 1.69	10.04 ± 1.40	-	7.32 ± 1.19	-	-
		Control	8-19	68	CBCT	9.29 ± 2.08	11.18 ± 1.80	-	7.82 ± 1.51	-	-
Luong et al. (29)	USA	HS	Adult	60	CBCT	10.15 ± 1.44	11.87 ± 1.60	-	7.89 ± 1.36	-	10.96 ± 1.50
Oktem et al. (40)	Turkey	HS (Male)	14-26 y	48	LCR	10.12 ± 2.33	11.63 ± 1.90	-	8.18 ± 1.38	-	-
		HS (Female)	14-26 y	46	LCR	9.34 ± 1.75	11.65 ± 1.35	-	7.88 ± 1.30	-	-
Gargi et al. (14)	India	HS (Male)	20-60 y	50	CBCT	9.29 ± 1.37	9.73 ± 1.29	-	8.39 ± 1.19	-	-
		HS (Female)	20-60 y	50	CBCT	9.02 ± 1.26	9.35 ± 1.43	-	7.81 ± 1.15	-	-

Table VII: Cont.

Study	Region	Samples	Age	N	Methods	STL (mm)	STD (mm)	STA (mm)	STM (mm)	STP (mm)	STW (mm)
Magat and Sener (30)	Turkey	HS (Male)	9-21 y	113	LCR	7.98 ± 1.69	10.78 ± 1.58	-	7.51 ± 1.37	-	-
		HS (Female)	9-21 y	180	LCR	8.10 ± 1.82	11.22 ± 1.65	-	7.71 ± 1.34	-	-
Ghaida et al. (15)	Jordan	HS	10-40 y	509	LCR	7.55 ± 1.72	-	-	6.32 ± 1.03	-	8.69 ± 1.34
Yasa et al. (57)	Turkey	HS	11-73 y	177	CBCT	10.32 ± 1.75	11.87 ± 1.66	-	7.99 ± 1.33	-	-
Muhammed et al. (34)	Bosnia	HS	8-28 y	180	LCR	9.68 ± 1.57	10.81 ± 1.33	-	6.64 ± 1.32	-	-
	Iraq	HS	8-28 y	180	LCR	8.89 ± 1.82	10.84 ± 1.68	-	7.54 ± 1.37	-	-
Sathyanarayana et al. (45)	India	HS (Male)	9-27 y	91	LCR	9.40 ± 1.63	11.20 ± 1.26	-	7.30 ± 1.31	-	-
		HS (Female)	9-27 y	89	LCR	8.90 ± 1.61	10.90 ± 1.31	-	7.30 ± 1.10	-	-
Turamanlar et al. (54)	Turkey	HS	17-70 y	101	CT	9.18 ± 1.91	11.48 ± 1.82	8.09 ± 1.65	7.71 ± 1.24	7.48 ± 1.34	10.41 ± 1.74
Hasan et al. (17)	Iraq	HS (Male)	1-70 y	49	CT	8.46 ± 1.61	10.79 ± 2.28	7.41 ± 1.80	7.44 ± 1.34	7.40 ± 1.43	8.21 ± 1.60
		HS (Female)	1-70 y	22	CT	8.42 ± 2.32	10.47 ± 2.01	6.81 ± 1.05	7.07 ± 1.22	7.03 ± 1.49	8.21 ± 1.73
Čutović et al. (12)	Serbia	Male with MP	18-30 y	30	LCR	-	-	-	9.33 ± 1.66	-	11.07 ± 1.45
		Control	18-30 y	30	LCR	-	-	-	7.55 ± 1.75	-	9.53 ± 1.34
Hasan et al. (18)	Malaysia	HS (Male)	0-35 y	113	CT	8.99 ± 1.86	10.26 ± 1.90	6.05 ± 1.39	6.61 ± 1.29	6.55 ± 1.42	8.35 ± 1.77
		HS (Female)	0-35 y	70	CT	9.19 ± 1.80	10.54 ± 1.90	6.60 ± 1.42	6.66 ± 1.19	6.54 ± 1.23	8.33 ± 1.56
Al-Nakib and Najim (2)	Iraq	Malposed Canine	13-25 y	40	LCR	8.22 ± 1.64	11.45 ± 1.45	-	7.86 ± 1.18	-	-
		Control	13-25 y	120	LCR	9.22 ± 1.97	11.56 ± 1.59	-	7.56 ± 1.15	-	-
Mustafa et al. (35)	Jordan	HS	10-40 y	509	LCR	-	-	-	6.32 ± 1.03	-	8.69 ± 1.34
Shaha et al. (49)	India	HS (Male)	25-70 y	116	CT	8.71 ± 1.73	-	3.87 ± 0.92	8.37 ± 1.85	3.97 ± 0.90	10.85 ± 1.73
		HS (Female)	25-70 y	84	CT	8.84 ± 1.93	-	3.86 ± 0.86	8.28 ± 1.83	3.95 ± 0.89	10.95 ± 1.91
Yasa et al. (56)	Turkey	Cleft	9-33 y	54	CBCT	10.83 ± 1.84	11.82 ± 1.56	-	7.74 ± 1.29	-	-
		Control	7-33 y	85	CBCT	9.78 ± 1.47	11.54 ± 1.38	-	7.52 ± 1.11	-	-
This study	Turkey	CM-I	6-63 y	32	CT	9.19 ± 1.76	10.90 ± 1.65	7.86 ± 1.87	8.10 ± 1.89	8.24 ± 2.21	9.41 ± 2.23
		Control	6-67 y	32	CT	9.26 ± 1.79	11.54 ± 2.05	7.77 ± 1.51	8.37 ± 1.34	9.03 ± 1.55	9.03 ± 1.94

***N:** Numbers of sides, **CT:** Computed tomography, **CBCT:** Cone-beam computed tomography, **LCR:** Lateral cephalometric radiograph, **HS:** Healthy subjects, **MP:** Mandibular prognathism.*

CONCLUSION

To the best of our knowledge, this investigation is the first to systematically evaluate ST morphology in patients with CM-I. Our findings revealed that the ST dimension of CM-I patients was similar to that of healthy subjects. The only difference in ST morphology was that CM-I patients had more round-shaped ST, whereas normal participants had more oval-shaped ST.

Declarations

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AUTHORSHIP CONTRIBUTION

Study conception and design: HO, OO, EA, SO
Data collection: OO, BCA
Analysis and interpretation of results: HU, AI, OB, EA
Draft manuscript preparation: HO, OB, HU, AI
Critical revision of the article: HO, OO, OB, BCA
All authors (HO, OO, BCA, EA, AI, HU, SO, OB) reviewed the results and approved the final version of the manuscript.

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