

# Morphometry of Sella Turcica, Anterior Clinoid Process and Carotico-clinoid Foramen among North Indian Population: A Cross-sectional Study

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## ABSTRACT

**Introduction:** Sella Turcica (ST), a complex bony landmark located on the body of sphenoid bone. Its lateral bony wall mainly consists of anterior and posterior clinoid processes and optic strut which bear a strong relationship with pituitary fossa.

**Aim:** To estimate various morphometric parameters of ST, Anterior Clinoid Process (ACP) with its anatomical variations, Optic Strut (OS) and Carotico-clinoid Foramen (CCF) among North Indian population group.

**Materials and Methods:** The present cross-sectional anatomical study was conducted on 30 adult dry fully ossified skull and 10 formalin fixed adult cadaveric cranial base present in the Department of Anatomy, SGT University Gurugram, Haryana, India, over a period of one year from January 2021 to December 2021 to evaluate various morphometric parameters such as anteroposterior, transverse diameter and depth of sellar region including ACPs with various bony distances. The range, mean and standard deviation of each parameters were measured by using Statistical Package for the Social Sciences (SPSS) latest version (version 21.0) and Student's t-test was

applied for bilateral comparison. Frequency of morphological variability of CCF was calculated in percentages.

**Results:** Among the 40 samples (both dry skull base and cadaveric skulls) the average dimensions of ST were 10.03±2.40 mm, 13.65±2.09 mm and 5.74±1.92 mm as anteroposterior, transverse and depth, respectively. The length, width and thickness of ACP were 11.22±1.74 mm, 8.04±1.73 mm and 2.27±0.70 mm, respectively. Also the length and width of OS were 3.61±0.78 mm and 3.72±0.47 mm, respectively. Significant difference was observed for distance of ACP to OS. The frequency of CCF was 10 (25%) among the total samples both bilateral and unilateral; out of which 8 (80%) of the samples presented with incomplete foramen, 1 (10%) presented contact type of CCF, and 1 (10%) of the samples exhibited a complete variety of CCF.

**Conclusion:** Bilateral significant difference was observed for the transverse diameter. The mean value for length of ACP was found significant. Detailed morphometry and morphological variations of structures present in sellar region is mandatory for the clinicians specially neurosurgeons and radiologist for the diagnosis and to decide the modality of treatment.

**Keywords:** Clinoid space, Hypophysis fossa, Internal carotid artery dimensions, Interclinoid osseous bar, Morphological variations, Optic strut

## INTRODUCTION

The ST is a saddle-shaped bony structure located on the upper surface of the body of sphenoid bone. The hypophysis fossa located in the centre of it lodges hypophysis cerebri or pituitary gland. So, morphological abnormalities of sellar area can lead to functional alteration of pituitary gland [1]. The lateral bony wall of ST is formed by the interval between anterior and posterior clinoid process as well as posterior margin of OS [2]. Anterior Clinoid Process (ACP) is situated on the medial edge of lesser wing of sphenoid and at the edge of dorsum sellae, the Posterior Clinoid Process (PCP) is located [3]. ACP and OS are two anatomical landmarks, very closely related to cavernous sinus located on either side of sellar region and bear a lot of clinical significance [4]. Complete or partial resection of ACP is a crucial step while performing surgical approach to cavernous sinus as well as pituitary tumours surgeries [3,4]. So, the clinicians especially neurosurgeons have to be well versed with the surgical anatomy of these bony landmarks while performing surgical interventions. Both morphological and morphometric variabilities of sellar region play a crucial role to increase the success of operative procedures in the sellar area [3]. Very small bony prominences are formed at the anterior most boundary of sella on its lateral side as Middle Clinoid Processes (MCP) [5]. Ligamentum ossification around the ST might form bony bridges that can connect clinoid processes to other structures. Sometimes, ACP and MCP get linked by osseous ligament leading to a foramen known as Carotico-clinoid

or Clinoido Caroticum Foramen (CCF) [5]. Internal Carotid Artery (ICA) can pass through this foramen. It was first introduced in 1855, by Henle J, [6] and was described as bony foramen or canal. Apart from foramen, interclinoid bridge is rarely formed can extends from ACP to PCP due to the ossification of interclinoid ligament at early stage of development [7]. Normally ICA passes on the medial side of ACPs and anterosuperior part of cavernous sinus but presence of carotico-clinoid canal can lead ICA to pass through the foramen itself [8]. As a result, while performing surgical interventions in the sellar region, there might be a chance to injury to the ICA. Studies have been undertaken on variations in morphometric parameters of ST among different population group like Turkish, Greeks and also South Indian especially on radiographs (cephelogram) [9-11]. But to the best of our knowledge, very few studies have been undertaken on the cadavers [2,12]. Previous studies have been reported for the occurrence of CCF among different population group like South Indian [3], East Indian [13] as well as other countries like Italy [14], Poland [15] but most of the studies performed on the radiographs and few on dry skulls [3,14,15]. Studies performed on the cadavers were less to find out the occurrence of CCF [2,13]. Another small bony bar is OS, a structure of variable dimensions connecting lesser wing of sphenoid with the body have also been mentioned in the previous literature [4]. This bony pillar is situated between optic canal and superior orbital fissure. Close proximity of OS with ACP can also lead to injury of optic nerve and ICA during surgical

intervention in the sellar region [16]. It has been observed that while approaching sellar area, this small bony strut is often removed for an easy access to the cavernous sinus [16]. Keeping this in mind, a morphometric analysis had been conducted both in dry skulls as well as cadavers among the North Indian population group. So, detailed anatomical knowledge of structures present in the sellar region will play a major role for the successful surgical interventions in the pituitary fossa and cavernous sinus.

**MATERIALS AND METHODS**

The present cross-sectional anatomical study was performed on the 30 adult dry fully ossified skulls of unknown sexes and 10 adult formalin fixed embalmed cadaveric skulls (to maximise the sample size for the study with minimal error) of North Indian population in Department of Anatomy, SGT University, Gurugram, Haryana, India, over a period of one year from January 2021 to December 2021.

**Inclusion criteria:** Only dry adult unbroken skulls and formalin fixed adult cadaveric heads without any gross evidence of pathologies were selected as study materials available in the Department of Anatomy, SGT University, Gurugram, Haryana, India.

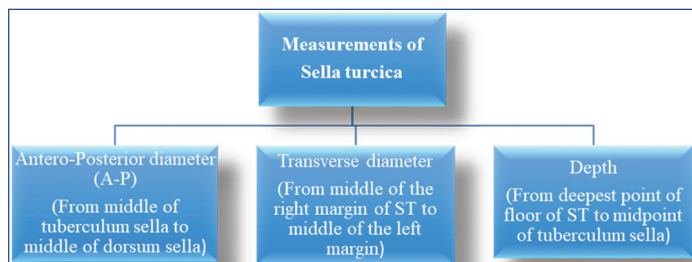
**Exclusion criteria:** All broken, pathologically deformed bony skulls and cadaveric specimens with gross pathology were excluded from the study.

**Sample size calculation:** According to convenient sampling and taking the value as reference according to Boyan N et al., [17] the minimum number of sample size was calculated. The sampling formula is  $N = z^2 \alpha \cdot p \cdot q / L^2$  where N is sample size; p is percentage;  $q = 1 - p$ , Type of error  $\alpha = 5\%$ , Allowable error  $L = 15\%$  of p. So, estimated sample size calculated was 40.

**Study Procedure**

The specimens were anonymised, randomly coded and de-linked from any identity sources (ICMR National guidelines for biomedical and health research involving human participants, ICMR, 2017, sec 5, Box 5.2) [18]. Among the cadaveric heads, sellar region was exposed by proper dissection after removing the calvaria and brain. Various morphometric parameters of ST [9] (displayed in [Table/Fig-1,2] including the morphometry of ACP, OS [2,17,19] and some bony distances were measured by the help of a digital vernier calliper in millimetres (mm) presented in [Table/Fig-3a,b].

Presence of CCF and its morphological variability whether complete (shows presence of bony ring or foramen), incomplete and contact form (foramen was apparently formed, but in which close inspection of the posterior wall revealed a dividing line or suture) types were also noted by subjective evaluation or by visual observation according to Keyes JE [20] and their percentages were calculated. Proper photography was conducted for the documentation.

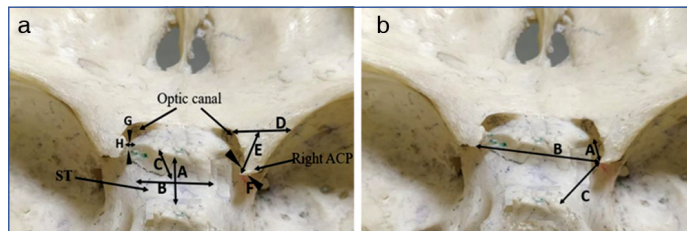


[Table/Fig-1]: Morphometric parameters measured for the Sella turcica [9,10].

Parameters for Bony landmarks		Dimension of various bony landmarks
Anterior Clinoid Process (ACP)	Length of ACP	From tip of the ACP to midpoint of basal width
	Width of ACP	From most medial border to lateral border of base of ACP
	Thickness of ACP	Measured at the tip of the ACP

Optic Strut (OS)	Vertical diameter	From anterior margin to the posterior margin of OS
	Transverse diameter	From medial margin to the lateral margin of OS
Parameters for bony distances		Anterior Interclinoid distance: Interval between tip of ACP of right-side to left-side
		Interclinoid distance from anterior to posterior side: Distance between tip of the ACP to PCP on both sides
		Distance between tip of ACP to optic strut on both sides

[Table/Fig-2]: Measurements were taken for ACPs, OS and various bony distances on both the sides in the skulls and in the cadaveric cranial cavity [2,17,19].



[Table/Fig-3]: a) Exhibits dimensions measured in millimetre (mm) for different structures of sellar region including ACPs and Optic struts (OS) in the skull. A-Antero-Posterior (A-P) diameter of Sella Turcica (ST), B- Transverse diameter of ST and C- Depth of ST D- Basal width of Anterior Clinoid Process (ACP), E- Length of ACP, F- Thickness of ACP, G- A-P diameter of Optic Strut (OS), H- Transverse diameter of OS; b) Denotes the parameters measured in millimetre (mm) for various bony distances of sellar region. A-distance measured from tip of ACP to OS, B- distance between tip of the two ACPs, C- From tip of ACP to tip of Posterior Clinoid Process (PCP).

**STATISTICAL ANALYSIS**

All morphometric dimensions were measured twice to decrease error and finally the average was taken. All the data acquired from the study was tabulated and analysed by using SPSS software (version 21.0). Bilateral comparison of the data was analysed by paired Student's t-test and value considered as significant ( $p < 0.05$ ). The graphs and tables were created in Microsoft Excel and Microsoft Word 2013.

**RESULTS**

In the present observational study, the mean AP diameter and transverse diameter of ST were  $10.03 \pm 2.40$  mm and  $13.65 \pm 2.09$  mm, respectively. The depth of sella was  $5.74 \pm 1.92$  mm. The AP diameter of OS lesser than the transverse diameter on both the sides. Significant difference was observed for the transverse diameter between right and left-side ( $p$ -value  $< 0.001$ ). The mean values for width and thickness of ACP on both sides were almost equal without any significant difference while the length of ACP was found significant. The descriptive analysis for all parameters of ST, OS and ACP has been displayed in [Table/Fig-4-6], respectively along with  $p$ -value. Descriptive statistics of various bony distances have been exhibited in [Table/Fig-7].

The morphological variability was also observed for the presence of ossified anterior clinoid ligament forming carotico-clinoid ligament and only 10 (25%) of the sample showed different types of carotico-clinoid foramen. Out of which 8 (80%) of the samples presented with incomplete foramen, 1 (10%) presented contact type of CCF, and 1 (10%) of the samples exhibited a complete variety of CCF and the morphological variability has been described in [Table/Fig-8] as graphical representation as well as photographic images has been displayed in [Table/Fig-9].

Parameters	Minimum (in mm)	Maximum (in mm)	Mean±SD (in mm)
Anteroposterior diameter	7.25	17.01	$10.03 \pm 2.40$
Transverse diameter	10.17	17.37	$13.65 \pm 2.09$
Depth	3.13	9.13	$5.74 \pm 1.92$

[Table/Fig-4]: The maximum, minimum, mean and standard deviation of Sella turcica (ST) (in mm).

Parameters	Right		Left		p-value
	Range (in mm)	Mean±SD (in mm)	Range (in mm)	Mean±SD (in mm)	
Anteroposterior diameter	1.8-4.7	3.61±0.78	2.3-4.3	3.11±0.58	0.04*
Transverse diameter	2.9-4.8	3.72±0.47	2.5-5.2	3.49±0.67	0.001*

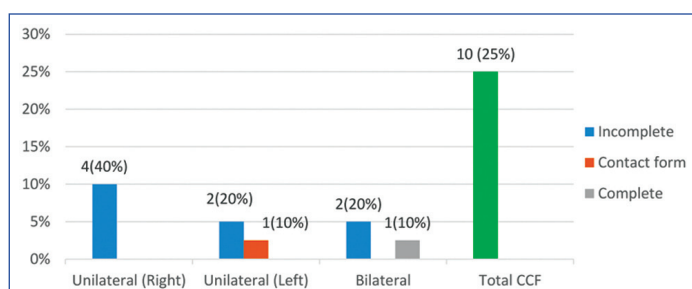
**[Table/Fig-5]:** The range and mean dimension with standard deviation of Optic Strut (OS) (in mm) on both sides; Paired student's t-test, \*level of significant p-value <0.05.

Parameters	Right-side		Left-side		p-value
	Range (in mm)	Mean±SD (in mm)	Range (in mm)	Mean±SD (in mm)	
Length	7.4-13.8	10.62±1.54	7.3-13.9	11.22±1.74	0.003*
Width	5.08-9.8	7.90±1.08	4.9-11.4	8.04±1.73	0.08
Thickness	1.2-3.43	2.19±0.60	1.4-4.06	2.27±0.70	0.4

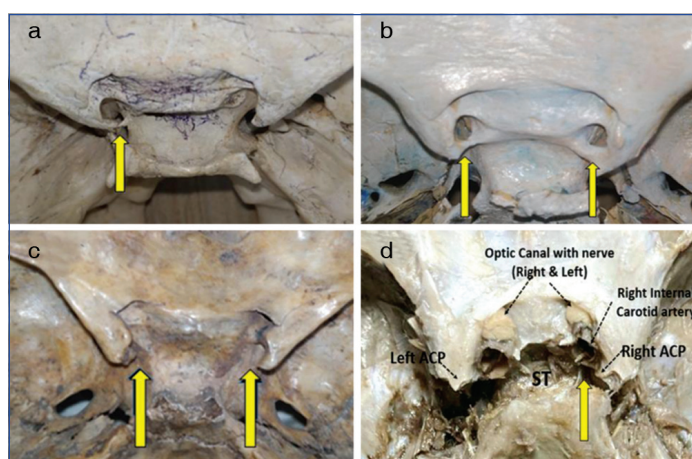
**[Table/Fig-6]:** The range and average dimensions in millimetre of Anterior clinoid process (ACP) on both sides; Paired student's t-test, \*level of significant p-value <0.05.

Parameters		Right-side		Left-side		p-value
		Range	Mean±SD	Range	Mean±SD	
Lateral bony wall distances	ACP to PCP	1.7-15.9	10.02±3.44	1.3-15.1	7.89±3.46	0.05*
	Tip of ACP to optic strut	7.2-13.1	8.57±1.17	4.98-10.6	7.79±1.17	0.0001*
Median bony wall distances	Between tip of two ACPs	Anteriorly	17.9±24.22	Posteriorly	20.92±2.01	

**[Table/Fig-7]:** Range and average bony distances of bilateral sellar region on lateral and median area in millimetre; Paired student's t-test, level of significant p-value <0.05.



**[Table/Fig-8]:** Percentage of morphological variability of arotico-clinoid foramen; unilateral, bilateral and total on both sides.



**[Table/Fig-9]:** Images displaying various types of CCF according to the subjective evaluation; a) Left-side contact form; b) Bilateral complete; c) Bilateral incomplete; d) Unilateral incomplete in cadaver.

## DISCUSSION

The ST is located at the centre of skull base inside the body of the sphenoid bone possesses intricate anatomical landmarks with numerous morphological variabilities. This complex anatomical bony structure has intimate relationship with cranial nerves, hypophysis cerebri, cavernous sinus as well as internal carotid artery [21]. So,

clinicians especially surgeons performing microsurgical interventions have to be well aware regarding this bony structure as well as need a better understanding for the variations encountered in this region [22,23]. That is why, morphometry and morphology of ST and related structures are mandatory for the clinicians to perform better surgical procedure for the well-being of the patients especially suffering from pituitary tumours. OS is one of the commonest bony points which is mostly detached while performing surgical interventions in the sellar region [24]. Not only OS but also removal of the ACPs will also provide extra space in the sellar region while instrumentation of sellar area [4]. So, various bony distances of OS and ACPs also play a role while executing surgical approach.

In present study, the distance between OS to ACP was significantly higher on the right-side as compared to left-side (p=0.0001). Also, it was observed that there was a significant difference in transverse diameter of OS (p=0.001). The length of OS was 3.61±0.78 mm on right-side and 3.11±0.58 mm on the left-side which was comparatively more among length observed in Korean population, where it was 2.9±1.15 mm. Among the Koreans the dimension was slightly longer on the left-side with statistical significance [25]. It was also observed among the Koreans that the distance of OS to ACP ranged from 1.3-9.3 mm but in the present study, the distance was ranging from 7.2-13.1 mm in the right-side and 4.98-10.6 mm in left-side, respectively. It was also observed among the Korean population that OS is most commonly attached to the anterior 2/5<sup>th</sup> of ACP [25].

In the present study, the width and thickness of ACPs of both sides were also measured but no statistically significant difference was observed on both the sides while the length of ACPs was found significant. The length was almost similar as observed among Turkish 12-11 mm [17], Nepalese 11-10 mm [26] and South Indian population group 12.6-12.9 mm [27]. The length of ACP was bilaterally 10-9.09 in the Korean population [25] and 10-9.3 in the population of Bosnia [28]. The width in present study was around 7.9-8.04 mm which was less than width observed by other population group like Turkish 12-4 mm [17], Koreans 9-9 mm [25], Nepalese 10-11 mm [26], and also of Bosnia population 9.4-9 mm [28]. Thickness of ACP was also less comparative to previous studies [17,25-28]. The mean length, width and thickness of ST in the present research were 10.03±2.40 mm, 13.65±2.09 mm and 5.74±1.92 mm, respectively. These diameters were in consonance with dimensions observed in a cadaveric study among Arabians population; only the depth 10.05 mm which was higher among Arabian population [29]. Among Greek [10] population in the cephalogram also the diameters of ST were less as compared to present study.

The distance between ACP to PCP on the right and left-sides in the present anatomical evaluation was 10.02±3.44 mm and 7.89±3.46 mm, respectively. But in the previous study among Chinese population on 530 skulls [2], it was observed as similar on the left-side as in the present study but among Chinese diameter on the right-side was much smaller. It was also observed among the Chinese, the occurrence of MCP and the mean area of Lateral Bony Wall (LBW) but without any significant statistical difference. [Table/Fig-10] shows the comparison of dimensions of ST and ACPs among other population groups [10,12,17,19,25-27].

The CCF develops as a result of ossification of carotico-clinoid ligament [4,5]. The presence of this foramen as well as the ossified ligament might cause clinical symptoms. It can cause entrapment of vascular structure like internal carotid artery and nerves; may cause entrapment syndrome. Numerous morphological variability has been mentioned regarding CCF in previous literature. In the present study, the total frequency of CCF was 25%; most of them were incomplete type and unilaterally situated as seen in other studies [2,3,5,7,25]. In study performed by Boyan N et al., among Turkish population, the frequency of bilateral CCF was higher [17]. In India,



Author (year)	Sample size (n)	Population group	Dimensions of ST	Dimension of ACPs		
					Right	Left
Lee HY et al., 1997 [25]	73	Korean	-	Length	9.97±1.58	9.09±1.67
				Width	9.26±1.43	9.29±1.39
				Thickness	5.44±1.02	5.19±1.12
Gupta N et al., 2005 [26]	35	Nepalese	-	Length	10.74±2.37	9.91±1.50
				Width	10.8±1.20	W- 11±1.12
				Thickness	5.13±1.02	5.33±0.96
Andredaki M et al., 2007 [10]	184	Greeks	-	Length - 7.1±1.7	-	-
				Height - 6.8±1.0		
				Width - 9.1±1.2		
Boyan N et al., 2011 [17]	34	Turkish	-	Length	11.5±1.9	11.4±1.8
				Width	12.4±1.7	4.4±1.2
				Thickness	T- 4.2±1.2	12.3±2.5
Kapur E and Mehic A, 2012 [19]	200	Bosnia and Herzegovina	-	Length	9.9±1.6	9.3±2.0
				Width	9.4±1.5	9.1±2.1
Swetha S, 2015 [27]	30	South Indian	-	Length	12.61±2.59	12.99±2.27
				Width	11.38±1.3	11.59±1.66
				Thickness	6.5±1.41	6.09±1.2
Sakran AM et al., 2015 [12]	36	Arabian	-	Length 11.57±0.14	-	-
				Depth 10.05±0.13		
				Width - 11.2±0.10		
Present study (2022)	40	North Indians	-	Length 10.03 ±2.40	Length	10.62±1.54
				Width 13.65 ±2.09	Width	7.90±1.08
				Depth 5.74 ±1.92	Thickness	2.19±0.60
						11.22±1.74
						8.04±1.73
						2.27±0.70

**[Table/Fig-10]:** Comparison of dimensions of Sella turcica (ST) and ACPs among other population groups [10,12,17,19,25-27].

most of the studies undertaken on South Indian population for the occurrence of CCF and mostly present on one side as unilateral. In the present anatomical study, contact type of variety of CCF was also observed among North Indian population group. [Table/Fig-11] shows the comparative analysis of incidence of CCF among different other population groups [3,7,17,19,25,28-30].

Author year	Sample size	Population	Bilateral CCF (%)	Unilateral CCF (%)	Total (%)
Inoue T et al., 1990 [7]	55 cadaveric heads	Florida	14.0	22.0	36.0
Lee HY et al., 1997 [25]	73 dry skulls	Korean	1.4	15.7	17.1
Erturk M et al., 2004 [28]	119 adult dry skulls and 52 adult cadaveric heads	Turkish	12.6	24.37	36.97
			9.61	23.08	32.69
Boyan N et al., 2011 [17]	34 dry skulls	Turkish	29.4	5.9	35.29
Kapur E and Mehic A, 2012 [19]	200 dry skulls	Bosnia and Herzegovina	7.5	9.25	16.75
Desai SD and Sreepadma S, 2012 [30]	223 dry skulls	South Indian	13.44	23.77	37.22
Souza AD et al., 2016 [3]	27 dry skulls	South Indian	18.52	25.93	44.4
Bansode SA et al., 2017 [29]	35 dry skulls	South Indian	5.71	14.28	20
Present study (2022)	40 skull base (both dry skull and cadaveric heads)	North Indian	7.5	17.5	25

**[Table/Fig-11]:** Comparative analysis of incidence of CCF among different other population groups [3,7,17,19,25,28-30].

### Limitation(s)

Sexual dimorphism was not observed in result. The number of dry specimens and cadaveric heads can be increased as sample

size to get a more valid results for providing a baseline data for the clinicians. Also anatomical landmarks in and surrounding sellar area are the most complicated landmark while approaching surgical interventions of hypophysis cerebri, and easily explore in the radiographs. So, radiological correlations can be added along with cadaveric sagittal sections in future as a project work.

### CONCLUSION(S)

Sella turcica is an important bony landmark situated in the middle cranial fossa. In present study mean AP diameter of sella turcica was 10.03±2.40 mm. The mean values for width and thickness of ACP on both sides were almost equal. The AP diameter of OS was less than the transverse diameter. In 25% of the sample different types of CCF were found. Knowledge of morphometric parameters as well as morphological variabilities of structures present in sellar region play an immense role to enhance the success rate while performing surgical interventions by the neurosurgeons. It also provides a baseline data regarding the incidence and morphological variabilities of CCF among North Indian population group which will help the clinicians to perform a better skillful surgeries on the middle cranial fossa.

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