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Original Article

The left and right differences in sella turcica bridging between sex analyzed by cone-beam computed tomography

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Introduction

The sella turcica (ST) is an anatomically important structure of the sphenoid bone.[1,2] A sella turcica bridge (STB) may be formed by the ossification of the interclinoid ligaments (ICL) between the anterior clinoid process (ACP) and the posterior clinoid process (PCP).[3-6] STB prevalence was significantly higher in skeletal Class III patients (16.7%-18%) than that in skeletal Class I (5%-9.4%).[7-9] However, distinguishing the left and right sides of the sella turcica on lateral cephalograms may be challenging due to the nature of two-dimensional (2D) images. There is a risk of taking distances from points belonging to different sides when measuring the dimension of the sella turcica, thus leading to an error in interclinoid distance (ICD) between ACP and PCP. Misjudgment of an STB may occur due to the overlapping of the clinoid processes on the lateral cephalogram. Changes in head orientation during imaging can cause left-right, anterior-posterior, or superior-inferior superimposition, leading to false-positive results of STB.[3,10,11] With the advance in imaging technology, the skull's three-dimensional (3D) structure can be reconstructed by cone-beam computed tomography (CBCT), further highlighting the limitations of 2D X-ray.[3,12] Several CBCT studies[13-17] measured the linear distance of the ST dimension on the sagittal plane (including sella length, sella depth, and sella diameter), and only a few studies mentioned the left and right ICD.[16,17]

Recent studies have shown sex differences in the structure of ST.[13,18] However, previous 2D[19-23] and 3D studies[1,2,14,24] took the opposite view. Standards for normal

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morphology must be established when describing the abnormal morphology in various craniofacial deformities and syndromes. The clinicians can use the dimensions and morphology of sella turcica as a reference to interpret and plan surgical procedures involving this region.[25]

This study aimed to investigate the differences between the left and right sides of ST and clarify the differences between the sexes. The null hypothesis of this study was that there would be no significant difference in the prevalence of an STB and sella turcica dimensions (1) between the left and right sides and (2) between males and females.

Materials and methods

Our study was reviewed and approved by the Institutional Review Board of Kaohsiung Medical University Hospital (KMUHIRB-E (II)-20210140). The CBCT images (New Tom VGi evo, Imola, Italy) of a total of 180 patients were recruited and investigated at the Department of Dentistry, Kaohsiung Medical University Hospital between July 2017 and May 2020. The exclusion criteria were systemic diseases, severe craniofacial abnormalities, cleft lip and palate, facial bone trauma, and unclear CBCT data. The craniofacial skeletal patterns of the study samples were classified into three groups based on the ANB angle ($0° \leq ANB \leq 40$: skeletal Class I; $ANB > 4°$: skeletal Class II; $ANB < 0°$: skeletal Class III).[19] This study included 90 males and 90 females (aged 20 to 40 years).

During the acquisition of the CBCT images, the patient maintains the natural head position and places the mandible in the centric-occlusal position. CBCT image data were output as a DICOM file, and the data were reconstructed into a 3D structural image using Soteria DcmRecons 3D image editing software version Alpha v0.7.0 (Soteria Biotech Ltd., New Taipei City, Taiwan). CBCT image calibration was performed by defining the head position based on the Frankfort horizontal plane (FH) (Porion-right, Porion-left, Orbitale-right). The FH plane was selected and calibrated as the axial plane; the plane perpendicular to the axial plane passing through the center of the ST was the sagittal plane, and the positions of the left and right orbits and the frontal plane were adjusted. Then the 3D structure of the cranial base, including the ST, was separately captured before the ST dimension was measured, in order to ensure that operators would be blinded.

The lateral cephalometric radiograph rendered by each patient's CBCT was also collected for inclusion in this study. The images of normal sella turcica and sella turcica bridging on a 2D lateral cephalogram are shown in Fig. 1. The sellar length measured in lateral cephalogram (SL-lc), sellar depth measured in lateral cephalogram (SD-lc), and diameter of sella turcica measured in lateral cephalogram (DST-lc) were measured according to Silverman (1957)[26] (Fig. 2). Sella-turcica bridging was based on the degree of ICL calcification, according to Leonardi et al.[3] "No bridge" is considered to be free of calcification if its length is greater than or equal to three-quarters of its diameter; "partial bridge" if it is less than or equal to three-quarters (ICL partially calcified); and "complete bridge" for radiographically identifiable connection between ACP and PCP (ICL fully calcified)[3]. The ImageJ software version 1.53a (Rasband, W.S., ImageJ, U.S. National Institutes of Health, Bethesda, MD, USA) was used on the right-lateral view cephalometric images rendered from CBCT for cephalometric measurements (Fig. 2).

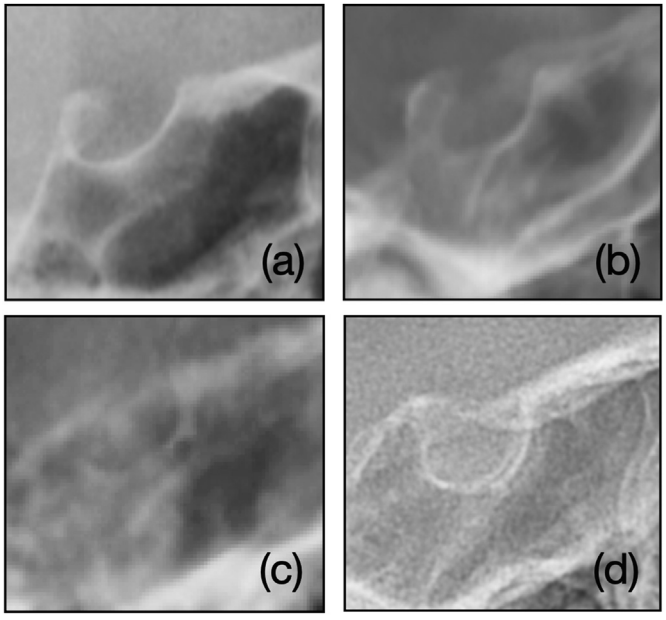

Fig. 1 Images of the sella turcica. (a) Normal sella turcica. (b)No bridge showed on the 2D lateral cephalogram. 3D CBCT confirmed a complete STB on the right side in the same patient. (c)Complete STB showed on an image of 2D lateral cephalogram. However, there is no bridging on both sides of the sella turcica in 3D CBCT. (d) Complete bridge showed on the 2D lateral cephalogram, and complete STBs on both the left and right sides in the same patient were confirmed by 3D CBCT.

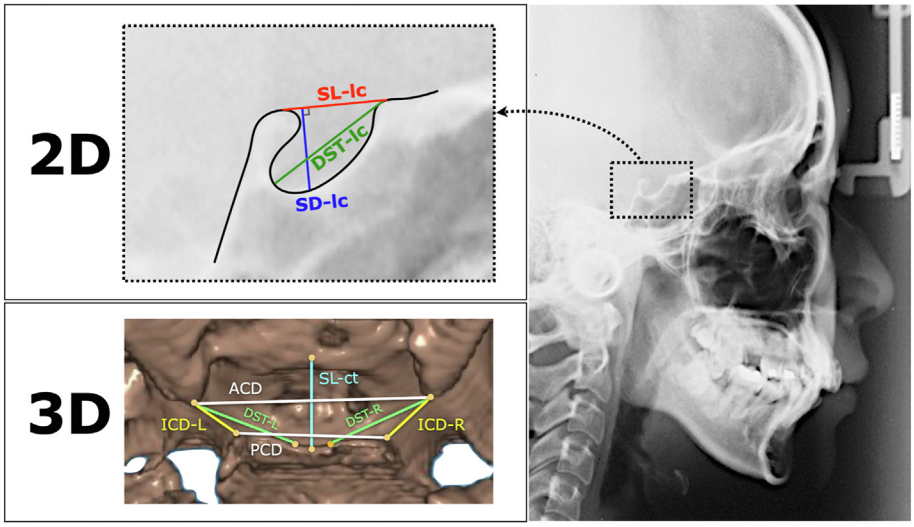

Fig. 2 Comparison between 2D lateral cephalometric X-ray film and 3D CBCT for sella-turcica dimensions.SL-lc: sella length measured in lateral cephalogram; SD-lc: sella depth measured in lateral cephalogram; DST-lc: diameter of sella turcica measured in lateral cephalogram; SL-ct: sella length measured in CBCT; SD—ct: sella depth measured in CBCT; ICD-L: interclinoid distance-L; ICD-R: interclinoid distance-R; DST-L: diameter of sella turcica-L; DST-R: diameter of sella turcica-R; ACD: anterior clinoid distance; PCD: posterior clinoid distance.

The definitions of measurement for the ST dimension are shown in Table 1, Fig 2 and Fig 3. The STB ratios on the left and right were calculated separately using objective and quantitative calculations to determine the degree of calcification of the ICL to show the type of bridging between the ACP and PCP. Based on this ratio, the STB was classified as complete (ratio $= 0$), partial ($0 <$ ratio $< 60\%$), or no bridge (ratio $> 60\%$).[11,27]

For the estimation of the number of samples, the **G*power** version 3.1 software (University of Düsseldorf, Düsseldorf, Germany) was used to conduct a post hoc test power analysis based on the collected data, using (1) the effect size of anterior clinoid distance (ACD) on the mean difference between genders, (2) the number of samples collected (sample size), (3) the first type error (alpha level) is 0.05. The analysis result shows that the test power (power) is 0.86, greater than 0.8, indicating that the number of samples is estimated as appropriate power.

SPSS Statistics statistical software version 20 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Statistical methods included kappa statistics to analyze consistency and reproducibility, descriptive statistics to analyze the prevalence of different types of sella bridging in the samples, and independent t tests and generalized linear models (GLMs) for comparing differences in sella turcica dimension among groups. The chi-square test was used to compare the differences in the distribution of various STBs on the left and right sides. The paired t-test was used to compare the differences in the sella turcica dimensions on the left and right sides of the same individual.

Results

After initial screening, 201 individuals (101 males and 100 females) were eligible for inclusion between July 2017 and May 2020. Twenty-one individuals (11 males and ten females) were excluded due to blurry images of the sella turcica, and thus 90 males and 90 females were included. The male and female samples' mean age was 26.66 ± 5.90 and 26.25 ± 5.53 years. There was no significant difference in age between the two groups ($P = 0.628$).

The current study's complete and partial bridge prevalence was 6.4% and 57.8%, respectively. The prevalence of STB on the right is significantly higher than on the left. There was no significant difference between the bridging types when comparing sex and the skeletal classification, as shown in Table 2. When interpreted by 3D CBCT images, seventeen patients had complete bridging on at least one side of the ST (9.44%, 17/180). When evaluated with a lateral cephalometric radiograph rendered by each patient's CBCT, 14.44% of patients (26/180) displayed complete bridge images (Table 3). The inconsistency of the above results may be due to the misjudgment caused by the overlapping of 2D images (Fig. 1).

As shown in Table 4, the sella depth measured in lateral cephalogram (SD-lc) was significantly different between skeletal patterns, with Class III being the smallest. There was no statistically significant difference in the various sella turcica dimensions measured by CBCT among the three skeletal relationships. The null hypothesis that there is no significant difference among skeletal relationships was accepted.

The ACD was significantly greater in males than females, regardless of skeletal groups. In Class III cases, the DST-L and DST-R were significantly more prominent in males than females (Table 5). Table 6 showed no significant differences between overall samples of males and females for linear measurements on lateral cephalogram. For measurement by CBCT, the DST-L, DST-R, ACD, and PCD were significantly more prominent in males than females. The null hypothesis that there is no significant difference between males and females was partially rejected.

Table 1 The definitions of the measurement for the dimensions of the sella turcica.

The dimensions of the sella turcica	Definitions
Sella length measured in CBCT (SL-ct)	The distance between Tuberculum Sella (TS) and Dorsum Sella (DS).
Sella depth measured in CBCT (SD-ct)	The vertical distance from the TS-DS connection to the deepest part of the floor of the sella turcica.
Diameter of sella turcica-L (DST-L)	The distance from ACP-L to the furthest point on the inner wall of the pituitary fossa on the left side (diameter point of sella turcica, left) (DpST-L).
Diameter of sella turcica-R (DST-R)	The distance from ACP-R to the furthest point on the inner wall of the pituitary fossa on the right side (diameter point of sella turcica, right) (DpST-R).
Interclinoid distance-L (ICD-L)	The distance between the apex of the ACP on the left side (ACP-L) and the apex of the PCP on the left side (PCP-L).
Interclinoid distance-R (ICD-R)	The distance between the apex of the ACP on the right side (ACP-R) and the apex of the PCP on the right side (PCP-R).
Anterior clinoid distance (ACD)	The distance between ACP-L and ACP-R. When a complete bridge exists, the midpoint on the narrowest part of the connection between the ACP's and PCP's tips is selected to measure the ACD.
Posterior clinoid distance (PCD)	The distance between PCP-L and PCP-R. When a complete bridge exists, the midpoint on the narrowest part of the connection between the ACP's and PCP's tips is selected to measure the PCD.
Sella turcica bridging ratio-L (STBr-L) (%)	The sella turcica bridging ratio of left side, which was calculated as ICD-L divided by SL-ct.
Sella turcica bridging ratio-R (STBr-R) (%)	The sella turcica bridging ratio of right side, which was calculated as ICD-R divided by SL-ct.

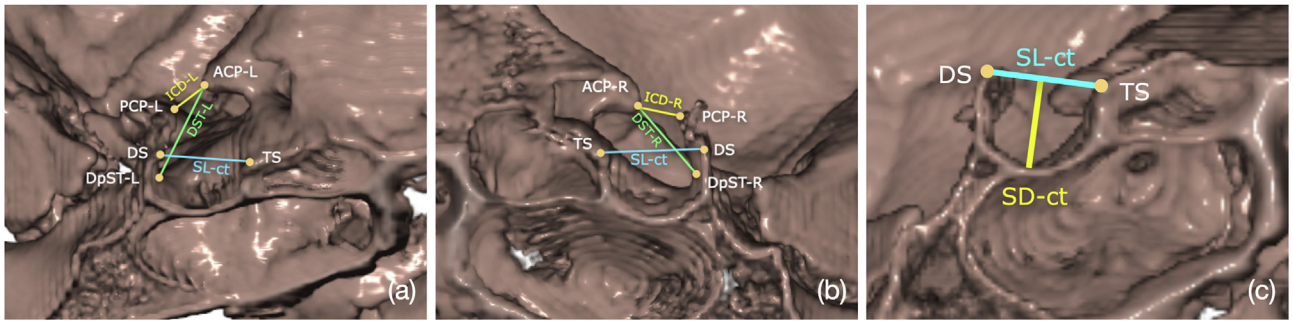

Fig. 3 The left side view and the right side view of the sella turcica on the cranial base. The sella-turcica dimensions measured on (a) the left side view and (b) the right side view. (c) The sella length (SL) and sella depth (SD) measured on the mid—sagittal plane in CBCT. The landmarks of the sella turcica: (1) tuberculum sella (TS): the midpoint on the anterior boundary of sella-turcica identified on the midsagittal plane; (2) dorsum sella (DS): the midpoint on the posterior boundary of the sell-turcica on the midsagittal plane; (3) anterior clinoid process, right (ACP-R): the apex of the anterior clinoid process on the right side; (4) anterior clinoid process, left (ACP-L): the apex of the anterior clinoid process on the left side; (5) posterior clinoid process, right (PCP-R): the apex of the posterior clinoid process on the right side; (6) posterior clinoid process, left (PCP-L): the apex of the posterior clinoid process on the left side; (7) diameter point of sella turcica, right (DpST-R): the furthest point on the inner wall of the pituitary fossa on the right side; (8) diameter point of sella turcica, left (DpST-L): the furthest point on the inner wall of the pituitary fossa on the left side. The sella-turcica dimensions: SL-lc: sella length measured in lateral cephalogram; SD-lc: sella depth measured in lateral cephalogram; DST-lc: diameter of sella turcica measured in lateral cephalogram; SL-ct: sella length measured in CBCT; SD—ct: sella depth measured in CBCT; ICD-L: interclinoid distance-L; ICD-R: interclinoid distance-R; DST-L: diameter of sella turcica-L; DST-R: diameter of sella turcica-R; ACD: anterior clinoid distance; PCD: posterior clinoid distance.

The ICD was significantly smaller on the right side; this was true in both sexes. The right STBr was significantly smaller in all samples and the females (Table 7). The null hypothesis that there is no significant difference between the left and the right side was rejected.

One month after all samples had been measured, the ST dimensions were re-measured in 30 randomly selected CBCT samples. The intraclass correlation coefficients (ICC) ranged from 0.78 to 0.99, indicating good and excellent reliability.

Discussion

The current study investigated the three-dimensional ST structure and demonstrated the right-side predominance of

Table 2 The distribution of sella-turcica bridging in 3D CBCT according to the side, the sex, and the skeletal classification.

	Sella-turcica bridging in 3D CBCT			Total	*P*
	Complete bridge (ratio = 0)	Partial bridge (0< ratio <60%)	No bridge (ratio ≥60%)		
Total	23 (6.4%)	208 (57.8%)	129 (35.8%)	360 (100.0%)	
Sex					
Male	14 (3.9%)	96 (26.7%)	70 (19.4%)	180 (50.0%)	0.196
Female	9 (2.5%)	112 (31.1%)	59 (16.4%)	180 (50.0%)	
Side					
Left	10 (2.8%)	93 (25.8%)	77 (21.4%)	180 (50.0%)	0.023*
Right	13 (3.6%)	115 (31.9%)	52 (14.4%)	180 (50.0%)	
Skeletal classification					
Class I	8 (2.2%)	78 (21.7%)	34 (9.4%)	120 (33.3%)	0.094
Class II	4 (1.1%)	68 (18.9%)	48 (13.3%)	120 (33.3%)	
Class III	11 (3.1%)	62 (17.2%)	47 (13.1%)	120 (33.3%)	

Sella-turcica bridging based on 60% cut-off (Camp JD, 1923): complete bridge (ratio = 0), partial bridge (0< ratio <60%), and no bridge (ratio ≥60%).
P: *P*-value. Statistically significant at $P < 0.05$, *: $P < 0.05$.

Table 3 The distribution of sella-turcica bridging in 2D lateral cephalogramaccording to the skeletal classification.

	Sella-turcica bridging in 2D lateral cephalogram			Total	*P*
	Complete bridge (Complete calcification)	Partial bridge (Sella <3/4 calcified)	No bridge (3/4 ≤ sella <1 calcified)		
Skeletal classification					
Class I	9 (5.0%)	14 (7.8%)	37(20.6%)	60 (33.3%)	0.157
Class II	6 (3.3%)	13 (7.2%)	41 (22.8%)	60 (33.3%)	
Class III	11 (6.1%)	5 (2.8%)	44 (24.4%)	60 (33.3%)	
Total	26 (14.4%)	32 (17.8%)	122 (67.8%)	180 (100.0%)	

Sella-turcica bridging based on the degree of ICL calcification (Leonardi et al., 2006): "No bridge" is considered to be free of calcification if its length is greater than or equal to three-quarters of its diameter; "partial bridge" if it is less than or equal to three-quarters (ICL partially calcified); and "complete bridge" for radiographically identifiable connection between ACP and PCP (ICL completely calcified).
P: *P*-value. Statistically significant at $P < 0.05$.

Table 4 The sella-turcica dimensions measured in lateral cephalogram and CBCT between skeletal groups.

Sella-turcica dimensions	Class I(n = 60)		Class II(n = 60)		Class III(n = 60)		F	*P* value	Significant
	Mean	SD	Mean	SD	Mean	SD			
Lateral cephalogram									
SL-lc	8.88	2.39	8.89	2.01	9.77	2.48	2.942	0.055	
SD-lc	7.40	1.54	7.42	1.32	6.19	1.47	14.333	<0.001	Class I, II > Class III
DST-lc	10.76	1.94	10.53	1.53	10.30	1.84	1.000	0.370	
CBCT									
SL-ct	10.87	1.78	10.98	1.60	10.80	1.54	0.174	0.841	
SD—ct	7.85	1.28	8.27	1.45	7.97	1.32	1.594	0.206	
DST-L	11.96	1.82	12.31	2.08	11.83	1.62	1.078	0.343	
DST-R	11.85	1.68	12.13	1.87	11.71	1.28	1.078	0.343	
ICD-L	5.49	2.68	6.35	2.00	5.69	2.80	1.925	0.149	
ICD-R	5.05	2.27	5.24	2.57	5.19	2.46	0.103	0.902	
ACD	24.86	2.31	25.06	2.83	24.46	2.17	0.912	0.404	
PCD	17.84	2.84	16.69	2.57	17.01	3.27	2.491	0.086	

P: *P*-value. Statistically significant at $P < 0.05$, *: $P < 0.05$, SL-lc: sella length measured in lateral cephalogram; SD-lc: sella depth measured in lateral cephalogram.
DST-lc: diameter of sella turcica measured in lateral cephalogram; SL-ct: sella length measured in CBCT; SD—ct: sella depth measured in CBCT; DST-L: diameter of sella turcica-L.
DST-R: diameter of sella turcica-R; ICD-L: interclinoid distance-L; ICD-R: interclinoid distance-R; ACD: anterior clinoid distance; PCD: posterior clinoid distance.

Table 5 The sella-turcica dimensions measured in lateral cephalogram and CBCT between skeletal groups by sex.

Group	Sella-turcica dimensions	Sex	Mean	SD	*P* value
Class I	SL-lc	Male	9.09	2.71	0.505
		Female	8.68	2.04	
	SD-lc	Male	7.18	1.37	0.277
		Female	7.62	1.69	
	DST-lc	Male	10.35	1.90	0.097
		Female	11.18	1.92	
	SL-ct	Male	11.20	1.80	0.147
		Female	10.53	1.72	
	SD—ct	Male	7.79	1.53	0.755
		Female	7.90	1.01	
	DST-L	Male	12.34	1.76	0.102
		Female	11.57	1.84	
	DST-R	Male	12.15	1.56	0.163
		Female	11.55	1.76	
	ICD-L	Male	5.63	2.90	0.683
		Female	5.34	2.48	
	ICD-R	Male	5.00	2.42	0.877
		Female	5.09	2.15	
	ACD	Male	25.59	2.35	0.014*
		Female	24.14	2.06	
	PCD	Male	18.39	2.58	0.132
		Female	17.28	3.02	
lass II	SL-lc	Male	9.35	1.85	0.070
		Female	8.42	2.08	
	SD-lc	Male	7.39	1.30	0.872
		Female	7.45	1.36	
	DST-lc	Male	10.48	1.50	0.795
		Female	10.59	1.58	
	SL-ct	Male	11.17	1.67	0.366
		Female	10.79	1.52	
	SD—ct	Male	8.31	1.55	0.845
		Female	8.24	1.36	
	DST-L	Male	12.77	2.47	0.089
		Female	11.85	1.50	
	DST-R	Male	12.63	1.91	0.039*
		Female	11.63	1.72	
	ICD-L	Male	6.86	1.98	0.045*
		Female	5.83	1.91	
	ICD-R	Male	5.53	2.66	0.381
		Female	4.95	2.49	
	ACD	Male	25.97	2.89	0.011*
		Female	24.14	2.49	
	PCD	Male	17.05	2.44	0.285
		Female	16.33	2.69	
Class III	SL-lc	Male	9.75	2.42	0.961
		Female	9.78	2.59	
	SD-lc	Male	5.98	1.42	0.276
		Female	6.39	1.51	
	DST-lc	Male	10.07	1.43	0.339
		Female	10.53	2.17	
	SL-ct	Male	10.71	1.70	0.646
		Female	10.90	1.39	
	SD—ct	Male	8.01	1.15	0.276
		Female	7.93	1.49	
	DST-L	Male	12.24	1.62	0.049*
		Female	11.42	1.54	
	DST-R	Male	12.23	1.31	0.001*
		Female	11.20	1.02	
	ICD-L	Male	5.54	3.10	0.684
		Female	5.84	2.52	
	ICD-R	Male	5.34	2.52	0.635
		Female	5.04	2.42	
	ACD	Male	25.49	1.64	<0.001*
		Female	23.43	2.17	
	PCD	Male	17.60	3.49	0.161
		Female	16.41	2.99	

SL-lc: sella length measured in lateral cephalogram; SD-lc: sella depth measured in lateral cephalogram; DST-lc: diameter of sella turcica measured in lateral cephalogram; SL-ct: sella length measured in CBCT; SD—ct: sella depth measured in CBCT; DST-L: diameter of sella turcica-L; DST-R: diameter of sella turcica-R; ICD-L: interclinoid distance-L; ICD-R: interclinoid distance-R; ACD: anterior clinoid distance; PCD: posterior clinoid distance.
P: P-value. Statistically significant at $P < 0.05$, *: $P < 0.05$; SD: standard deviation.

the STB. Our study showed that it might be related to the smaller ICD on the right than on the left side, regardless of gender. We found that mainly the ACD (represented the anterior sellar width) and PCD (described the posterior sellar width) described sexual dimorphism among all the ST dimensions. We could not clarify this result by studying lateral cephalograms.[3,12] Previous CBCT studies have focused on ST measurements related to the midsagittal plane.[1,13,18,14] Only a few studies compared the transverse dimension of ACD but did not mention the PCD.[2,28] To the best of our knowledge, no studies compared the ACD, PCD, and even the left-right borders of the sella turcica at the same time. Additionally, the prevalence of left-right differences in the STB among adults in Taiwan had not been reported previously.

The present study showed that the percentage of complete STB appearing on the right side (3.6%) was significantly higher than that on the left side (2.8%) (Table 2). Natsis et al.[29] proposed that interclinoid calcification in the sellar region can exhibit side predominance, which represents differences in dominance of the left and right sides. Both Natsis et al.[29], Erturk et al.[30], and Kapur and Mehic[31] found right-side predominance, which coincides with our study. Left-right differences in variations of sellar structure can also be seen in the caroticoclinoid foramen (CCF), which was formed by the calcified connection of the ACP and the middle clinoid process (MCP).[32] Lee et al.[32] found that the incidence of CCF among Korean individuals was higher on the right side (9.2%) than on the left side (5.5%).

Our study revealed that the ACD and the PCD did not differ between skeletal groups. The ACD is more prominent in males than in females regardless of skeletal groups. Therefore, we propose that the primary factor affecting ACD is sexual dimorphism rather than skeletal relationships. Previous studies confirmed our findings.[25,28] The PCD was more remarkable in males but not as significant as the

Table 6 The sella-turcica dimensions measured in lateral cephalogram and CBCT between sex.

Sella-turcica dimensions	Male (n = 90)				Female (n = 90)				*P* value
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Lateral cephalogram									
SL-lc	9.40	2.34	4.09	15.79	8.96	2.30	3.89	14.48	0.205
SD-lc	6.85	1.49	3.58	10.36	7.15	1.61	3.62	12.09	0.191
DST-lc	10.30	1.61	6.34	13.78	10.77	1.91	5.69	15.74	0.079
CBCT									
SL-ct	11.03	1.72	7.07	15.23	10.74	1.54	6.60	13.83	0.241
SD—ct	8.04	1.42	4.60	11.22	8.02	1.29	5.42	11.16	0.936
DST-L	12.45	1.97	7.57	16.98	11.61	1.62	6.85	14.67	0.002
DST-R	12.34	1.61	8.03	17.10	11.46	1.53	8.45	15.40	<0.001
ICD-L	6.01	2.74	0.00	13.40	5.67	2.30	0.00	11.36	0.369
ICD-R	5.29	2.52	0.00	9.70	5.03	2.33	0.00	9.63	0.462
ACD	25.68	2.34	16.85	30.31	23.90	2.25	19.70	30.08	<0.001
PCD	17.68	2.89	11.43	24.97	16.67	2.90	9.48	23.54	0.021

SL-lc: sella length measured in lateral cephalogram; SD-lc: sella depth measured in lateral cephalogram; DST-lc: diameter of sella turcica measured in lateral cephalogram; SL-ct: sella length measured in CBCT; SD—ct: sella depth measured in CBCT; DST-L: diameter of sella turcica-L; DST-R: diameter of sella turcica-R; ICD-L: interclinoid distance-L; ICD-R: interclinoid distance-R; ACD: anterior clinoid distance; PCD: posterior clinoid distance.
P: *P*-value. Statistically significant at $P < 0.05$, *: $P < 0.05$; n: number; SD: standard deviation; Min: Minimum; Max: maximum.

Table 7 The sella-turcica dimensions measured in CBCT between left and right sides.

Sella-turcica dimensions		Left					Right					*P* value
		N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	
All	ICD	180	5.84	2.53	0.00	13.40	180	5.16	2.42	0.00	9.70	<0.001*
	DST	180	12.03	1.85	6.85	16.98	180	11.90	1.63	8.03	17.10	0.242
	STBr	180	53.94%	22.49%	0.00%	99.85%	180	47.75%	22.39%	0.00%	91.28%	0.009*
Male	ICD	90	6.01	2.74	0.00	13.40	90	5.29	2.52	0.00	9.70	0.005*
	DST	90	12.45	1.97	7.57	16.98	90	12.34	1.61	8.03	17.10	0.512
	STBr	90	55.01%	24.36%	0.00%	99.85%	90	48.74%	23.75%	0.00%	89.58%	0.075
Female	ICD	90	5.67	2.30	0.00	11.36	90	5.03	2.33	0.00	9.63	0.003*
	DST	90	11.61	1.62	7.57	16.98	90	11.46	1.53	8.03	17.10	0.308
	STBr	90	52.87%	20.54%	0.00%	93.11%	90	46.77%	21.03%	0.00%	91.28%	0.045*

ICD: interclinoid distance; DST: diameter of sella turcica; STBr: sella-turcica bridge ratio.
P: *P*-value. Statistically significant at $P < 0.05$, *: $P < 0.05$; N: number; SD: standard deviation; Min: Minimum; Max: maximum.

ACD (Table 5 and Table 6). They may be related to anatomically regional differences in the growth and development of the anterior and posterior cranial base between different sex.[33] An early ossification and maturation of the posterior cranial base result in the growth difference mentioned above.[34] Before the age of five, the ACD of both males and females grows rapidly, but in late childhood (ages 12–15 years), there is another increase in the ACD width in males that do not occur in females, especially at the peak of adolescent growth.[33] When treating patients with abnormalities in cranial base growth, these differences between males and females should be considered.[33,35]

Sexual dimorphism appears in craniofacial trait morphology, such as the bony brow ridge and the chin more prominent in males, which play a vital role in sex determination in forensic medicine and archaeology.[36,37] The differences in the linear length of the jaw bones between males and females in the cephalometric analysis are found primarily in the characteristics of the mandible, including the more protruding position of the mandible and the longer mandibular length (Ar-Gn, articulare-gnathion) in males than in females.[17] In addition, there is a positive correlation between Ar-Gn length and ACD, however, not in PCD.[17]

Based on our results, the DST-L and DST-R were larger in males. However, the DST-lc (measured on lateral cephalogram) did not exhibit a sex difference. The divergent results may be because the definition of a diameter of ST in 3D is different from that of 2D, and wider ACD of males may result in potentially longer DST-L and DST-R (Fig. 2 and Fig. 3). There was no sex difference in sellar length (SL-ct and SL-lc) (Table 6). It should be possible to exclude the influence of the anterior-posterior sellar distance on diameter.

In the present study, the prevalence of STB did not differ significantly between the sexes or skeletal relationships, unlike previous 2D studies.[9,10,19,21] Actual differences in 3D space were difficult to tell with 2D measurements (Fig. 1 and Fig. 2). Moreover, the STB may exhibit different

morphologies, such as the fusion with the MCP in previous 2D studies.[3] It may have been misidentified as STB (fusion of ACP and PCP), leading to an overestimated STB rate.[11] Therefore, comparison with the findings of previous studies is challenging.[11] Acevedo et al.[16] confirmed that lateral cephalogram overestimates complete STB patients compared to CBCT. Although correctly distinguishing between no bridge and partial bridge, lateral cephalogram is still considered a suitable screening modality.[16] Differences in study results may be due to differences in ethnic groups, other anatomical markers representing the same dimension, superimposition of images of related anatomical structures, and different magnification levels.[2,18]

Taner et al.[15] measured 80 Turkey patients' sella length, depth, diameter, and volume. Whereas the ACD, PCD, ICD-left, and ICD-right are not measured. They only included normal facial appearance and occlusion samples, so there is no way of knowing whether there are differences between different skeletal relationships.

Silveira et al.[13] studied 95 Brazilians' CBCT to compare the size difference of the sella turcica between Class II and Class III patients prior to orthognathic surgery. They also measured the length, depth, diameter, and volume of the sella turcica but did not compare the difference between left-right and anterior-posterior width. Since Class I was not included in the sample, comparison with the normal craniofacial relationship was not easy.

Acevedo et al.[16] studied American subjects and compared the correctness of CBCT and lateral cephalogram in judging sella turcica bridging. They included 185 samples (67 males and 118 females), but the proportion of male and female samples is very different. Moreover, only the sella length, depth, and diameter were measured, whereas the ACD and PCD were not. Therefore, it was not possible to compare whether there was a difference between the anterior and posterior widths of sella turcica. Furthermore, their inclusion criteria only mentioned that any malocclusion could be included, indicating that it is impossible to determine whether the proportions of various skeletal classifications are consistent.

Previous 2D studies[9,19,21] and 3D CBCT studies[1,2,14,28] found no significant difference in sella length between males and females, which coincides with our results. On the contrary, Turamanlar et al.[18] and Axelsson et al.[38] indicated a longer sellar length in males. The present study results showed that the depth of the sella (SD-ct and SD-lc) did not differ significantly between males and females, which coincides with previous studies.[1,14,19,21,22,28,38] However, Hasan et al.[39] believed that sex differences in the sella turcica were present only at the anterior sella height. The different results in different studies may be due to the close relationship between race and heredity.[2,18] Morphological variation in the ST region may be induced by disorders of growth and development related to craniofacial or pituitary variation or by age-related factors (normal physiological processes).[10]

Our study sample is limited to adults aged 20–40 years; thus, it is difficult to evaluate the cranial growth and development with age. Future studies should include a larger sample size and include adolescents and children to investigate further the influence of age-related changes and sex differences on ST dimensions and morphology.

In conclusion, our study confirmed that the right-side predominance of STB was related to the significantly smaller ICD on the right side than on the left side in both sexes. The ST dimensions exhibited sex differences, including ACD, PCD, DST-L, and DST-R. Our study may provide detailed information to help radiologists, orthodontists, maxillofacial surgeons, and neurosurgeons familiarize themselves with the region's typical structural and morphological changes to identify images reflecting pathological changes correctly.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article.

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