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Original Article

Retrospective study of the styloid process in a Taiwanese population using cone beam computed tomography

Mio-leng Chu [a], Chia-Hui Chen [b], Chen-Yi Lee [c**], Yuk-Kwan Chen [a,d,e*]

[a] School of Dentistry, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan
[b] Department of Medical Imaging and Radiological Sciences, I-Shou University, Kaohsiung, Taiwan
[c] School of Dental Hygiene, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan
[d] Division of Oral Pathology & Maxillofacial Radiology, Department of Dentistry, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan
[e] Oral & Maxillofacial Imaging Center, Kaohsiung Medical University, Kaohsiung, Taiwan

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Background/purpose: Review of literature, evaluation of the styloid process (SP) using cone beam computed tomography (CBCT) has not been performed in a Taiwanese population. Our study aimed to evaluate the different characteristics of SP using CBCT in a Taiwanese population.

Materials and methods: CBCT scans of 121 patients (55 males, 66 females; mean age, 27 ± 9.09 years) were evaluated to assess the length, morphological type, calcification pattern, and angulation of the SP. A SP length greater than or equal to 30.00 mm is considered to indicate an elongated SP (ESP). ESP was classified in terms of morphology as Type I: uninterrupted; Type II: pseudo-articulated; or Type III: segmented. The calcification pattern of SP was categorized as Type A: calcified outline; Type B: partially calcified; Type C: nodular; or Type D: completely calcified. The transverse and sagittal angles between the bilateral SP were also measured.

Results: One-hundred and nine patients had a bilateral SP and 12 patients had a unilateral SP. The mean SP length was 26.34 ± 7.44 mm. Forty-two (34.71%) patients had an ESP. The most common ESP morphology was Type 1, followed by Type II, then Type III, while the calcification pattern prevalence was of the descending order Type B, Type A, Type C, and Type D. The mean transverse and sagittal angles were 66.90 ± 5.41° and 26.67° ± 6.50°, respectively.

* Corresponding author. School of Dentistry, College of Dental Medicine, Kaohsiung Medical University, 100 Shih-Chuan 1st Road, Kaohsiung, 80708, Taiwan. Fax: +886 7 3210637.
** Corresponding author. School of Dental Hygiene, College of Dental Medicine, Kaohsiung Medical University, 100 Shih-Chuan 1st Road, Kaohsiung, 80708, Taiwan. Fax: +8867 3210637.
E-mail addresses: cylee@kmu.edu.tw (C.-Y. Lee), k0285@ms22.hinet.net (Y.-K. Chen).

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Conclusion: The present study was the first to evaluate the characteristics of SP in a Taiwanese population using CBCT. The data contribute a useful basis for clinical investigation of the SP in future.

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Introduction

The styloid process (SP) is a thin bony projection arising from the posterior part of the lower surface of the petrous portion of the temporal bone immediately in front of the stylomastoid foramen.[1] Most commonly, the length of the SP is 20—25 mm.[2] The SP is classified as an elongated SP (ESP) when the length is greater than or equal to 30 mm.[2] The reported frequency of ESP as detected by cone beam computed tomography (CBCT) has varied from 15.10%[3] to 63.95%[3,4] (Table 1).

Langlais et al.[5] proposed the classification of ESP according to morphology as follows: Type I: uninterrupted; Type II: pseudo-articulated; and Type III: segmented (Fig. 1A). Langlais et al.[5] also categorized the calcification pattern of SP as Type A: calcified outline; Type B: partially calcified; Type C: nodular; and Type D: completely calcified (Fig. 1B). The angles between the bilateral SP are classified as the transverse (anterior-posterior view) and the sagittal angle (mediolateral view).[6]

Radiographic examinations are crucial to detect the presence of the SP. Conventional two-dimensional radiography carries the possibility of overlapping of the SP with adjacent anatomical structures and the occurrence of distortions. CBCT can overcome the above-mentioned drawbacks.[3,7,8] Furthermore, reviewing the literature, evaluation of the SP using CBCT has not been performed in a Taiwanese population. Therefore, we aimed to assess the prevalence, length, angulation, morphological type and calcification pattern of the SP using CBCT in a Taiwanese population.

Materials and methods

Demographic and imaging records of CBCT scans showing the SP in 121 Taiwanese patients were retrospectively reviewed. The patients were treated at Kaohsiung Medical University Hospital for orthodontic treatment or dental implant fabrication. The Institutional Review Board of Kaohsiung Medical University Hospital, Taiwan (IRB: KMUH-IRB-980345) approved the study. The exclusion criteria included the presence of bone disease, trauma history, surgery, congenital anomalies, malignant pathology in the maxillofacial region, and history of orofacial pain. CBCT radiographs with a questionable SP were excluded.

CBCT scans were acquired with an I-CAT Cone Beam 3-D Dental Imaging System (Imaging Sciences International, Hatfield, PA, USA). During the CBCT examination, the patients maintained the head in a natural position. The exposure settings were 26.9 s and 120 kV, the voxel size was 0.25 mm, and the field of view was 16 × 13 cm. Digital Imaging and Communications in Medicine (DICOM) data measurements were obtained using i-CATVision™ VisionQ (ver. 1.8.1.10) vision software.

The panoramic view was reconstructed from the CBCT data. The length of the SP was measured from the caudal margin on the tympanic pleat to the tip of the process. The ESP morphology and SP calcification pattern were categorized according to the classifications of Langlais et al.[5] The transverse angle was measured between the line connecting the base of the bilateral SP and the long axis of each of the right and left SP from the three-dimensional view (Fig. 1C). The sagittal angle was measured as the vertical line passing from the cranial base of the SP, which was vertical to the Frankfort plane on the lateral view (Fig. 1D). All measurements were made independently by two examiners (M—I Chu and Y—K. Chen), both of whom have experience in acquiring and interpreting CBCT scans. When there was disagreement between the two examiners, an agreement was reached by mutual discussion.

The Chi-square test, independent-sample t-test and one-way ANOVA were conducted using SPSS (version 20.0). A P value less than 0.05 was considered statistically significant.

Table 1 Previous studies on the frequency of elongated styloid process (ESP) using cone beam computed tomography from different countries.

Authors (year)	Frequency of ESP (%)	Sample size	Country
Öztunç et al. (2014)[19]	54.00	208	Turkey
Donmez et al. (2017)[3]	15.10	1000	Turkey
Garapati et al. (2017)[18]	51.90	52	India
Missias et al. (2018)[23]	45.10	1000	Brazil
Buyuk et al. (2018)[4]	63.95	1000	Turkey

ESP: ≥ 30 mm.

Results

A total of 230 SPs were observed from the CBCT images of 121 patients (55 males; 66 females; mean age: 27 ± 9.09 years; range, 9—53 years). The longest ESP was 54.76 mm (Fig. 2A). Different representative types of ESP morphology are presented in Fig. 2B—D, and representative images of differing calcification patterns of the SP are shown in Fig. 2E—H. Representative transverse angle and sagittal angle images are shown in Fig. 1C and D.

As shown in Table 2 109 patients had a bilateral SP, and 12 a unilateral SP. In the unilateral SP group, the number of

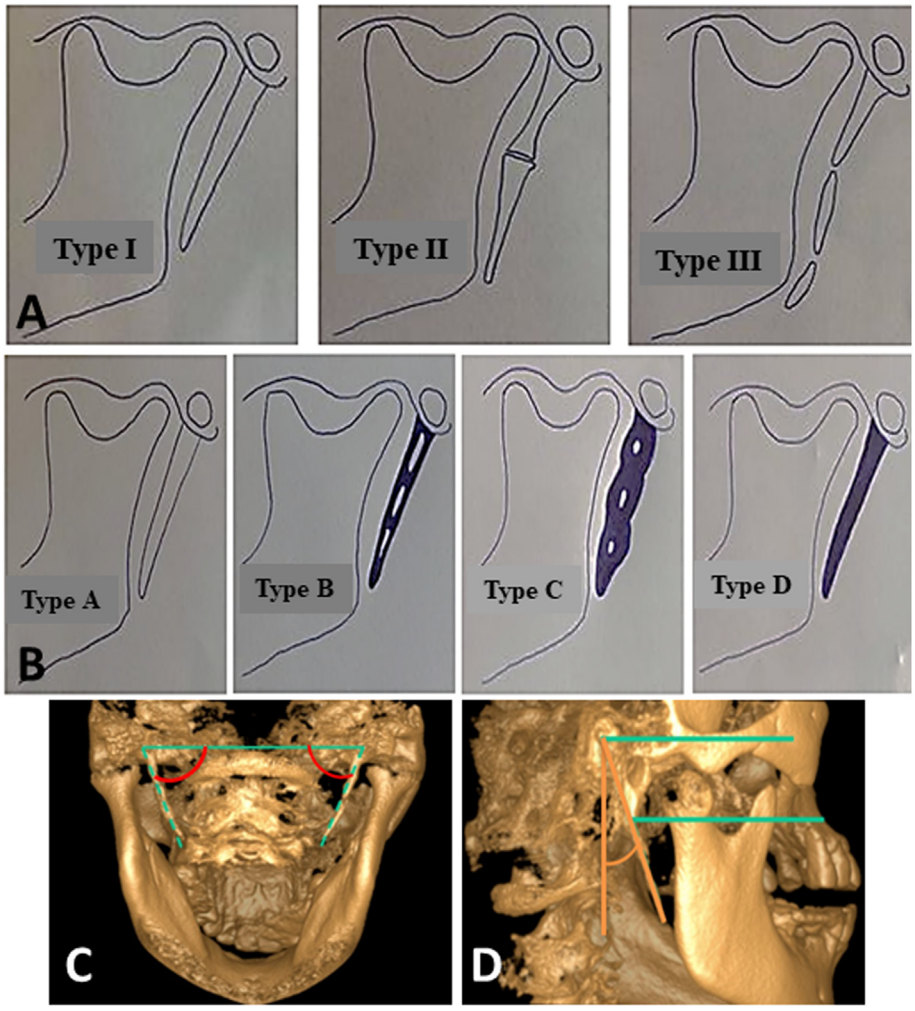

Figure 1 (A) Classification of morphology of elongated styloid process (ESP): Type I, uninterrupted elongated; Type II, pseudo-articulated; Type III, segmented. (B) Classification of calcification pattern of SP: Type A, calcified outline; Type B, partially calcified; Type C, nodular; Type D, completely calcified. (C) Transverse angle is measured between the line connecting the base of the bilateral SP and the long axis of each of the right and left SP. (D) Sagittal angle is measured as the vertical line passing from the cranial base of the SP, which is vertical to the Frankfort plane on the lateral view.

female subjects was higher than the male subjects, while in the bilateral SP group, the number of female subjects with non-ESP on both sides was higher than that of the male participants. Equal numbers of female and male subjects had a unilateral ESP, while the number of male participants with a bilateral ESP was higher than that of the female subjects.

The frequency of ESP in relation to age and gender is shown in Table 3. Of the total study population, 34.71% (22 males; 20 females) were found to have an ESP. The highest ESP frequency was observed in the age range of 21–30 years (46.28%). A significant difference was noted when comparing the mean length of the SP between the ESP and non-ESP groups (Tables 4 and 5). On the other hand, most ESP and non-ESP subjects were in the range of 21–30 years in this study (Table 6).

The SP morphology (both left and right) with the highest frequency was Type I (Table 7), while that for male and female subjects was Type I and Type III, respectively. On the other hand, the SP calcification category (left and right) with the highest frequency was Type B, followed by Type A, Type C and Type D (Table 8). Type B was the category with the highest frequency in the left SP group, the right SP group, and both male and female groups.

The distributions of the mean angles (transverse; sagittal) of the SP according to gender and elongation status are presented in Table 9. The mean sagittal angle of the whole male population (ESP and non-ESP), 25.51 $\pm$ 6.23°, was smaller than that of the female population (27.62 $\pm$ 6.59°). There were significant differences between the male and female subjects in the sagittal angle of the SP for the non-ESP group ($P = 0.001$) and the whole study population ($P = 0.015$).

The distributions of the mean angles (transverse, sagittal) of the SP according to gender and site (left/right) are presented in Table 10. The mean transverse angle of the left SP for the whole study population was 66.09 $\pm$ 5.10°, which was lower than that of the right

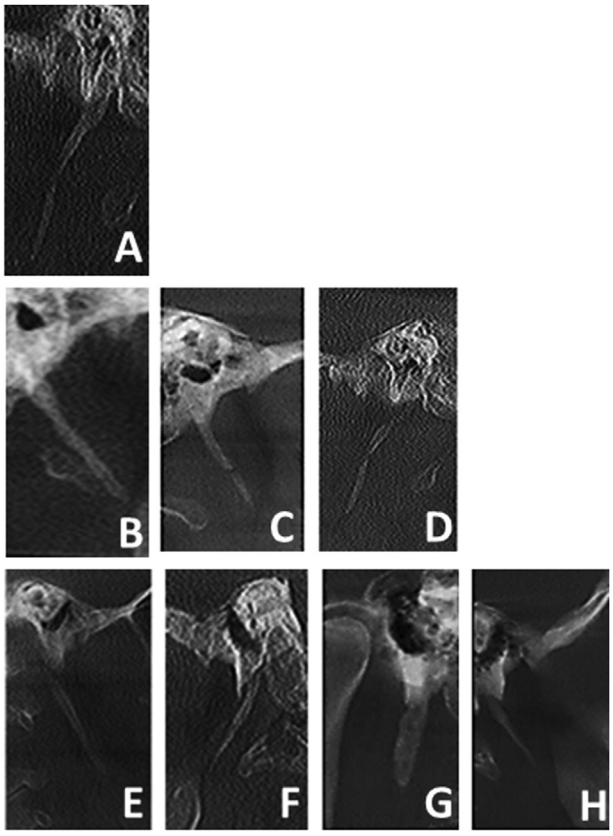

Figure 2 The longest elongated styloid process (ESP) in the study (A). Different representative types of ESP morphology: Type I, uninterrupted elongated (B); Type II, pseudo-articulated (C); Type III, segmented (D). Different representative calcification patterns of SP: Type A, calcified outline (E); Type B, partially calcified (F); Type C, nodular (G); Type D, completely calcified (H).

Table 2 Comparison of the frequency of unilateral/bilateral styloid process (SP), non-elongated SP (ESP) and ESP according to gender.

		Male	Female	Total
		N (%)[a]	N (%)[a]	N (%)[a]
Unilateral SP	Non-ESP	4 (33.33)	8 (66.67)	12 (100.00)
	ESP	—	—	—
Bilateral SP	Both non-ESP	29 (43.28)	38 (56.72)	67 (100.00)
	Unilateral ESP	12 (50.00)	12 (50.00)	24 (100.00)
	Bilateral ESP	10 (55.56)	8 (44.44)	18 (100.00)

N: Number of subjects in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
[a] Percentage of male/female subjects with respect to category.

counterpart (67.72 $\pm$ 5.61°). The mean sagittal angulation of the left side SP for the whole study population was 26.36 $\pm$ 6.40°, which was lower than that of the right counterpart (27.00 $\pm$ 6.61°). A significant difference in the mean transverse angle of the SP was observed between the male and female subjects in the left SP group ($P = 0.017$); a significant difference in the mean transverse angle in the left and right SP groups was also noted ($P = 0.026$). With regards to the sagittal angle of the SP, there was a significant difference between the male and female subjects in the right SP group ($P = 0.018$).

The distributions of the mean angles (transverse, sagittal) of the SP according to age and elongation status are summarized in Table 11. Most participants were of the age range 21—30 years, both ESP and non-ESP subjects. In this age group, the mean transverse and sagittal angles in the ESP group were 67.48 $\pm$ 6.89° and 27.33 $\pm$ 6.38°, respectively, whereas those of the non-ESP group were 65.99 $\pm$ 5.64° and 28.52 $\pm$ 7.48°, respectively. A significant difference in the mean sagittal angle of the SP was observed between different age groups for the non-ESP subjects and the whole study population ($P < 0.001$).

Discussion

The current study, to the best of our knowledge, was the first to investigate the characteristics of the SP in a Taiwanese population using CBCT. In the study, the incidence of ESP was 34.71%, and the mean SP length was 26.34 mm. The most common morphological types of ESP were Type I and Type II, while the most common calcification pattern of SP was Type B. The mean SP transverse angle was 66.90°, and the mean SP sagittal angle was 26.67°.

A number of studies have reported an increased SP length with respect to increasing age.[9—14] Gokce et al.[15] suggested that age may be associated with elongation of the SP. However, the highest frequency of ESP in the present study was within the age group of 21—30 years (45.24%), and the lowest frequency was noted at $\geq$ 41 years (9.52%). The difference between the observations of the current study and the results of previous studies could be due to the fact that most participants in our study were under 40 years of age.

Buyuk et al.[4] reported a lower frequency of ESP in female subjects (29.86%) than in males (42.69%), which was consistent with our findings (female: 16.53%; male: 18.18%). On the other hand, an almost equal number of participants with ESP on either side was observed in the current study, whereas Yılmaz et al.[16] reported a lower frequency of left ESP (10.20%) than the right counterpart (15.90%). Additionally, two studies showed that ESP was more common on the left side.[10,17]

Garapati et al.[18] reported a mean length of 31.50 mm for the right SP and 30.30 mm for the left. Yılmaz et al.[16] found that the mean length of the right SP was 23.56 mm, and that of the left SP was 22.00 mm. Buyuk et al.[4] also demonstrated that the mean length of the right SP was significantly longer than that of the left SP. The aforementioned results were comparable with our findings (right SP: 26.64 mm; left SP: 26.05 mm).

We found that Type I was the most common morphological type of SP in the whole study population, which was consistent with the results of a study conducted by Donmez et al.[3] The most common morphological type of SP in the male subjects was Type I, while that in the female

Table 3 Comparison of elongated styloid process (ESP) frequency in relation to age and gender.

Age (years)	Male		Female		Total	
	N (%)	ESP (%)	N (%)	ESP (%)	N (%)	ESP (%)
≤ 20	14 (25.45)[a] (53.85)[b]	2 (9.09)[a] (33.33)[b]	12 (18.18)[a] (46.15)[b]	4 (20.00)[a] (66.6)[b]	26 (21.49)[a]	6 (14.29)[a]
21–30	21 (38.18)[a] (37.50)[b]	12 (54,55) (63.16)[b]	35 (53.03)[a] (62.50)[b]	7 (35.00)[a] (36.84)[b]	56 (46.28)[a]	19 (45.24)[a]
31–40	15 (27.27)[a] (51.72)[b]	7 (31.82)[a] (53.85)[b]	14 (21.21)[a] (48.28)[b]	6 (30.00)[a] (46.15)[b]	29 (23.97)[a]	13 (30.95)[a]
≥ 41	5 (9.09)[a] (50.00)[b]	1 (4.55)[a] (25.00)[b]	5 (7.58)[a] (50.00)[b]	3 (15.00)[a] (75.00)[b]	10 (8.26)[a]	4 (9.52)[a]
Total	55 (100.00)[a] (45.45)[b]	22 (100.00)[a](52.38)[b]	66 (100.00)[a] (54.55)[b]	20 (100.00)[a] (47.62)[b]	121 (100.00)[a]	42 (100.00)[a] (34.71)[c]

N: Number of subjects in the study population;
ESP: ≥30 mm.
[a] Percentage of male/female/total subjects in a certain age group with respect to the total male/female study population.
[b] Percentage of male/female subjects in a certain age group with respect to the total study population in each group (number/ESP).
[c] Percentage of subjects with ESP in the whole study population.

Table 4 Comparison of the mean elongated styloid process (ESP) and non-ESP lengths according to gender.

	Length			
	ESP		Non-ESP	
	n	[a]Length (mm)	n	[a]Length (mm)
Male	32	33.67 ± 1.27	74	23.72 ± 5.24
Female	28	35.18 ± 8.95	96	23.35 ± 5.37
Total	60	32.37 ± 6.75*	170	23.51 ± 5.30*
	ESP + non-ESP			
	n		**[a]Length (mm)**	
Male	106		26.72 ± 6.69	
Female	124		26.02 ± 8.04	
Total	230		26.34 ± 7.44	

n: number of SPs in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
*Significant difference between length of ESP and length of non-ESP ($P < 0.001$).
[a] Mean ± standard deviation.

participants was Type III, which was in agreement with the results of Buyuk et al.[4] who stated that Type I was the most common type in males, and Type II and Type III were most frequent in females.

Buyuk et al.[4] reported a significant difference in the morphological type of SP between genders, and a borderline significant difference was noted in the present study ($P = 0.055$); in contrast, Öztunç et al.[19] demonstrated no significant difference.

The most common SP calcification pattern was Type B in the current study. In addition, Type B was most common in the left SP and right SP groups, which was consistent with the study of Öztunç et al.[19] Moreover, the calcification pattern with the highest frequency for the male subjects was Type B, followed by Type A, Type C, and Type D; the same trend was observed for the female participants. It is worthy of note that Öztunç et al.[19] reported no significant difference in the SP calcification pattern in terms of gender and site, with the exception that Type C was significantly more common in the male participants with a right SP, and in the female subjects with a left SP.

Table 5 Comparison of the mean elongated styloid process (ESP) and non-ESP lengths according to site (left/right) and gender.

	Left				Right			
	ESP		Non-ESP		ESP		Non-ESP	
	n	[a]Length	n	[a]Length	n	[a]Length	n	[a]Length
Male	14	34.13 ± 3.95	39	23.82 ± 4.94	18	33.33 ± 4.09	35	23.62 ± 5.63
Female	15	34.81 ± 10.25	48	22.77 ± 5.02	13	35.62 ± 7.57	48	23.92 ± 5.71
Total	29	34.48 ± 7.74*	87	23.24 ± 4.98*	31	34.27 ± 5.81**	83	29.10 ± 5.64**
	ESP + non-ESP				**ESP + non-ESP**			
	n		**[a]Length**		**n**		**[a]Length**	
Male	53		26.54 ± 6.54		53		26.91 ± 6.90	
Female	63		25.64 ± 8.34		61		26.41 ± 7.76	
Total	116		26.05 ± 7.55		114		26.64 ± 7.35	

n: number of SPs in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
*Significant difference between length of ESP and length of non-ESP in the left group ($P < 0.001$).
**Significant difference between length of ESP and length of non-ESP in the right group ($P < 0.001$).
[a] Mean ± standard deviation.

Table 6 Comparison of the mean elongated styloid process (ESP) and non-ESP lengths according to age.

Age (years)	ESP		Non-ESP		Total SP (ESP + non-ESP)	
	n	[a]Length (mm)	n	[a]Length (mm)	n	[a]Length (mm)
≤ 20	8	31.68 ± 0.72	43	22.66 ± 5.52	51	24.07 ± 6.05
21–30	28	34.48 ± 8.45	74	23.90 ± 4.89	102	26.80 ± 7.68
31–40	19	35.97 ± 5.85	39	23.35 ± 5.63	58	27.48 ± 8.22
≥ 41	5	32.04 ± 1.58	14	24.54 ± 5.95	19	26.51 ± 6.14
Total	60	34.37 ± 6.75	170	23.51 ± 5.30	230	26.34 ± 7.44

n: number of SPs in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
[a] Mean ± standard deviation

Table 7 Comparison of elongated styloid process (ESP) morphologies with respect to gender and site (right/left).

ESP morphology		Male	Female	Total
		n (%)	n (%)	
Type I	Left	7 (21.88)[a] (63.64)[b]	4 (14.29)[a] (36.36)[b]	11 (18.33)[d]
	Right	8 (25.00)[a] (66.67)[b]	4 (14.29)[a] (33.33)[b]	12 (20.00)[d]
	Left + Right	15 (46.88)[a] (65.22)[c]	8 (28.57)[a] (34.78)[c]	23 (38.33)[d]
Type II	Left	5 (15.63)[a] (55.56)[b]	4 (14.29)[a] (44.44)[b]	9 (15.00)[d]
	Right	8 (25.00)[a] (61.54)[b]	5 (17.86)[a] (38.46)[b]	13 (21.67)[d]
	Left + Right	13 (40.63)[a] (59.09)[c]	9 (32.14)[a] (40.91)[c]	22 (36.67)[d]
Type III	Left	2 (6.25)[a] (22.22)[b]	7 (25.00)[a] (77.78)[b]	9 (15.00)[d]
	Right	2 (6.25)[a] (33.33)[b]	4 (14.29)[a] (66.67)[b]	6 (10.00)[d]
	Left + Right	4 (12.50)[a] (26.67)[c]	11 (39.29)[a] (73.33)[c]	15 (25.00)[d]
Total		32 (53.33)[d]	28 (46.67)[d]	60 (100.00)[d]

Type I: uninterrupted elongated; Type II: pseudo-articulated; Type III: segmented;
n: Number of SPs in the study population.
[a] Percentage of gender (male/female).
[b] Percentage of left/right side for each of Type I, II, and III.
[c] Percentage of left+right side for each of Type I, II, and III.
[d] Percentage of male/female/total (male+female) with respect to the study population.

Table 8 Comparison of styloid process (SP) calcification patterns with respect to gender and site (left/right).

Calcification pattern		Male	Female	Total
		n (%)	n (%)	
Type A	Left	18 (16.98)[a] (50.00)[b]	18 (14.52)[a] (50.00)[b]	36 (15.65)[d]
	Right	16 (15.09)[a] (48.48)[b]	17 (13.71)[a] (51.52)[b]	33 (14.35)[d]
	Left + Right	34 (32.08)[a] (49.28)[c]	35 (28.23)[a] (50.72)[c]	69 (30.00)[d]
Type B	Left	20 (18.87)[a] (44.44)[b]	25 (20.16)[a] (55.56)[b]	45 (19.57)[d]
	Right	20 (18.87)[a] (46.51)[b]	23 (18.55)[a] (53.49)[b]	43 (18.70)[d]
	Left + Right	40 (37.74)[a] (45.45)[c]	48 (38.71)[a] (54.55)[c]	88 (38.26)[d]
Type C	Left	12 (11.32)[a] (50.00)[b]	12 (9.68)[a] (50.00)[b]	24 (10.43)[d]
	Right	8 (7.55)[a] (36.36)[b]	14 (11.29)[a] (63.64)[b]	22 (9.57)[d]
	Left + Right	20 (18.87)[a] (43.48)[c]	26 (20.97)[a] (56.52)[c]	46 (20.00)[d]
Type D	Left	3 (2.83)[a] (27.27)[b]	8 (6.45)[a] (72.73)[b]	11 (4.78)[d]
	Right	9 (8.49)[a] (56.25)[b]	7 (5.65)[a] (43.75)[b]	16 (6.96)[d]
	Left + Right	12 (11.32)[a] (44.44)[c]	15 (12.10)[a] (55.56)[c]	27 (11.74)[d]
Total		106 (46.09)[d]	124 (53.91)[d]	230 (100.00)[d]

Type A: calcified outline; Type B: partially calcified; Type C: nodular; Type D: completely calcified;
n: Number of SPs in the study population.
[a] Percentage of gender (male/female).
[b] Percentage of left/right side for each of Type A, B, C, and D.
[c] Percentage of left+right side for each of Type A, B, C, and D.
[d] Percentage of male/female/total (male+female) with respect to the study population.

Table 9 Comparison of elongated styloid process (ESP) and non-ESP mean angles (transverse, sagittal) according to gender and elongation status.

	Angle (transverse)			
	ESP		Non-ESP	
	n	[a]Angle (°)	n	[a]Angle (°)
Male	29	67.69 ± 6.69	67	67.48 ± 4.55
Female	28	65.72 ± 5.74	91	66.59 ± 5.44
Total	57	66.72 ± 6.26	158	66.95 ± 5.09
	Total SP (ESP + non-ESP)			
	n		**[a]Angle (°)**	
Male	96		67.54 ± 5.25	
Female	119		66.38 ± 5.50	
Total	215		66.90 ± 5.41	
	Angle (sagittal)			
	ESP		**Non-ESP**	
	n	**[a]Angle (°)**	**n**	**[a]Angle (°)**
Male	30	27.68 ± 6.19	71	24.59 ± 6.06**
Female	28	26.81 ± 6.12	96	27.86 ± 6.73**
Total	58	27.26 ± 6.12	167	26.47 ± 6.63
	Total SP (ESP + non-ESP)			
	n		**[a]Angle (°)**	
Male	101		25.51 ± 6.23*	
Female	124		27.62 ± 6.59*	
Total	225		26.67 ± 6.50	

n: number of SPs in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
*Significant difference between male and female subjects in the whole study population ($P < 0.05$).
**Significant difference between male and female subjects in the non-ESP group ($P < 0.01$).
[a] Mean ± standard deviation.

Table 10 Comparison of the styloid process (SP) mean angles (transverse, sagittal) according to gender and site (left/right).

	Angle (transverse)			
	Left		Right	
	n	[a]Angle (°)	n	[a]Angle (°)
Male	48	67.39 ± 4.05*	48	67.70 ± 6.26
Female	60	65.05 ± 5.62*	59	67.74 ± 5.07
Total	108	66.09 ± 5.10**	107	67.72 ± 5.61**
	Angle (sagittal)			
	Left		**Right**	
	n	**[a]Angle (°)**	**n**	**[a]Angle (°)**
Male	51	25.65 ± 6.45	50	25.36 ± 6.05***
Female	63	26.93 ± 6.35	61	28.34 ± 6.80***
Total	114	26.36 ± 6.40	111	27.00 ± 6.61

n: number of SPs in the study population.
*Significant difference in transverse angle between male and female subjects in the left group ($P < 0.05$).
**Significant difference in transverse angle between left and right SP groups ($P < 0.05$).
***Significant difference in sagittal angle between male and female subjects in the right SP group ($P < 0.05$).
[a] Mean ± standard deviation.

CBCT has been recommended to assess the transverse and sagittal angles of the SP[20]; these angles are considered important because small alterations may provoke significant clinical symptoms.[21] The mean transverse angle was reported in previous studies to range from 61.50° to 74.00°,[4,6,16,18,19] similar to our results. Öztunç et al.[19] reported a smaller mean transverse angle in ESP (68.13°) as compared with non-ESP (70.01°), which was compatible with our results, in which a smaller mean transverse angle was noted in the ESP group (66.72°) than in the non-ESP group (66.95°). It has been suggested that a narrow transverse SP angle (<65°) may lead to clinical complaints due to compression of adjacent structures.[22]

Statistical analysis showed that the mean transverse angle of the left SP (66.09°) was significantly smaller than that of the right side (67.72°) in the present study. To our knowledge, this was the first study to employ statistical analysis to compare the transverse angle of the SP between sides. Despite Garapati et al.[18] reporting the mean transverse angle of the SP on the left (61.60°) and the right (61.50°), and Yılmaz et al.[16] reporting 71.79° on the left and 70.39° on the right; , no statistical evaluations were performed in these two studies. Furthermore, comparing the mean transverse angle of the SP in the male and female participants with a left SP, our results showed a significant smaller angle in the female subjects (65.05°) than the males (67.39°), which was consistent with two previous studies.[6,22]

There have been limited studies of the sagittal angle of the SP.[4,6,16] Ilgüy et al.[6] reported a mean sagittal angle of 25.60°, while Yılmaz et al.[16] reported 27.43° for the right mean sagittal angle and 27.70° for the left. Our study yielded similar results, the mean sagittal angle of the SP being 26.67°.

A significant difference was noted in the mean sagittal angle of the SP between the male (24.59°) and female (27.86°) non-ESP groups in the present study, in that the male participants in our study population had a significantly smaller sagittal SP angle than the females in the non-ESP group. There was also a significant difference in the mean sagittal angle of the SP between the male (25.51°) and female subjects (27.62°) in the whole study population. This result was consistent with the studies of Ilgüy et al.[6] and Buyuk el al.[4]

Male subjects were found to have a significantly smaller SP sagittal angle (25.36°) on the right side than the females (28.34°) in the present study. On the other hand, the mean sagittal angle of the SP for the left side was 26.36°, which was smaller than that of the right side (27.00°); however, Yılmaz et al.[16] observed that the mean sagittal angle of the SP on the left side was larger than that on the right side.

In conclusion, the current study was the first to examine the SP in a Taiwanese population using CBCT. CBCT has

Table 11 Comparison of the elongated styloid process (ESP) and non-ESP mean angles (transverse, sagittal) according to age and elongation status.

Age (years)	Angle (transverse)					
	ESP		Non-ESP		Total SP (ESP + non-ESP)	
	n	[a]Angle (°)	n	[a]Angle (°)	n	[a]Angle (°)
≤ 20	8	68.23 ± 5.46	39	66.75 ± 5.06	47	67.00 ± 5.10
21–30	26	67.48 ± 6.89	67	65.99 ± 5.64	93	66.40 ± 6.02
31–40	18	65.65 ± 6.41	38	68.51 ± 4.44	56	67.59 ± 5.27
≥ 41	5	64.20 ± 1.92	14	68.07 ± 2.52	19	67.05 ± 2.91
Total	57	66.72 ± 6.26	158	66.95 ± 5.09	215	66.90 ± 5.41
Age (years)	**Angle (sagittal)**					
	ESP		**Non-ESP**		**Total SP (ESP + non-ESP)**	
	n	**[a]Angle (°)**	**n**	**[a]Angle (°)**	**n**	**[a]Angle (°)**
≤ 20	8	26.95 ± 5.48	41	26.14 ± 5.77*	49	26.27 ± 5.68**
21–30	26	27.33 ± 6.38	73	28.52 ± 7.48*	99	28.21 ± 7.20**
31–40	19	28.39 ± 6.55	39	24.94 ± 5.16*	58	26.08 ± 5.83**
≥ 41	5	23.00 ± 2,00	14	21.00 ± 2.83*	19	21.53 ± 2.74**
Total	58	27.26 ± 6.12	167	26.47 ± 6.63*	225	26.67 ± 6.50**

n: number of SPs in the study population;
Non-ESP: < 30 mm; ESP: ≥ 30 mm.
*Significant difference in sagittal angle between age groups in the non-ESP subjects ($P < 0.001$).
**Significant difference in sagittal angle between age groups in the whole study population ($P < 0.001$).
[a] Mean ± standard deviation.

proved to be an important imaging tool for the measurement and assessment of the SP. The results of this study could provide valuable information to inform future study of the SP in Taiwan.

Declaration of competing interest

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

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