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Original Article

An evaluation of the prevalence of elongated styloid process in Taiwanese population using digital panoramic radiographs

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Abstract *Background/purpose:* Styloid process (SP) was an anatomical structure located in front of the stylomastoid foramen and the occurrence of styloid process elongation was uncertainly reported. The purpose of this study was to survey, using digital panoramic radiography, the lengths of styloid process (SP) and the prevalence of elongated SP in the Taiwanese population. Their relationships with age, gender and laterality were also determined.
Materials and methods: A total of 539 patients (including 53 that were referred from the Department of Otorhinolarygngology with clinical symptoms) were studies retrospectively. Panoramic radiographic examinations were performed on all these patients at the Outpatient clinics of the Department of Stomatology, Taichung Veterans General Hospital between January 2019 and December 2019. Patients were divided into groups according to their age and gender. The length of SP from the base of temporal bone junction to the tip of the process was measured using the Sirona software. Data were analyzed using SPSS version 22.0 based on tests of Chi-square, Mann–Whitney U and Kruskal Wallis tests. Statistical significance was set at $p < 0.05$.
Results: A total of 539 (240 males and 299 females) digital panoramic radiographs were measured and evaluated in this study. The mean length of SP was 30 $\pm$ 0.7 mm on the right side and 29 $\pm$ 0.7 mm on the left side. The average length of SP on both sides was 29.5 $\pm$ 0.7 mm. In those cases with symptomatic Eagle syndrome, the mean length of SP was 32 $\pm$ 0.8 mm on the right side and 33 $\pm$ 0.8 mm on the left side (average 32.5 $\pm$ 0.8 mm). These lengths were statistically different between the general population and the symptomatic patients. Furthermore, the mean length of SP was 29 $\pm$ 0.7 mm in females and 30 $\pm$ 0.7 mm in males. The length of the SP grew progressively with age, and was

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more clearly seen within subjects from 41 to >60 years of age ($p < 0.005$). Meanwhile, the prevalence of elongated SP in our study was 41.5% on the right side and 36.2% on the left side, with female predominance.

Conclusion: The mean length of SP was 30 ± 0.7 mm (right side) and 29 ± 0.7 mm (left side). The prevalence of elongated SP was 41.5% on the right side, and 36.2% on the left side. Our findings were consistent with some previous studies that were differences related with age, and were more prominent in those patients with symptoms.

Introduction

The styloid process (SP) is a cylindrical cartilaginous bone arising from the posterior site of the temporal bone. SP is located in front of the stylomastoid foramen. Together with the styloid ligament and the small horn of the hyoid bone of the styloid process, they form the styloid apparatus.[1—3] It is typically 16—30 mm long with variations across individuals, and even between the left and right sides of the same person.[4]

The elongation of SP is an anatomical feature in the general population. It may cause compression on nerves and blood vessels leading to neck symptoms, orofacial pain, dysphagia and referred otalgia that are characteristic symptoms of Eagle syndrome as first reported by WW Eagle in 1937.[4—6] Styloid process is normally 16—30 mm in length with variations related to ethnic groups and geographical regions. About 2%—4% of the general populations are estimated to have elongated styloid processes. The majority of them are asymptomatic.[3,7—9] In the past, morphological aspects of SP were evaluated using different methods like measurements on human skulls,[10—12] digital panoramic radiographs,[2—4,7,13—18] computed tomography (CT) and cone beam computed tomography (CBCT).[19,20] Although CBCT has high precision with 3D measurements, digital panoramic radiography remains the primary resource for epidemiological studies because of its easy calibration despite compromised accuracy.

In the lack of any radiological investigation specifically focused on elongated styloid process in Asia region, the aim of this study was to evaluate the average length of SP and the prevalence of elongated SP using the digital orthopantomography in a Taiwanese population. We also analyzed its variation and relationship with gender, age and laterality and compared results particularly with those in patients with symptomatic Eagle syndrome.

Materials and methods

Our study protocol was ethical approved by the Institutional Review Board of Taichung Veterans General Hospital, Taiwan. Digital radiological images of a total of 539 patients (240 males and 299 females), including 53 patients (26 male and 27 female) referred from the Department of Otorhinolaryngology with suspicious of symptomatic Eagle syndrome were retrospectively reviewed and evaluated. These patients all received digital panoramic radiographic examinations at the outpatient clinics of the Department of Stomatology, Taichung Veterans General Hospital between January 2019 and December 2019. Patients were divided into groups according to their age and gender. Patients had ages ranging from 18 to 99 years (mean 48.2 years). Radiographic examinations were taken from a digital panoramic system (Dentsply Sirona, Orthophos XG, Bensheim, Germany) under the exposure settings (8 MA, 69Kvp and 14s) as recommended by the manufacturers. X-ray images were display directly on a 4G monitor. The length of the styloid process was measured from the point where the styloid process left the bottom of the tympanic plate to the tip of the process, regardless of whether or not the styloid process had been segmented (Fig. 1). The measurements were done with the manufacturer supplied software (EBM dental, Taichung, Taiwan). Data were confirmed by an oral radiologist and a dentist of our hospital. Intra- or inter-observer variability was determined at the limit of <5%. The data were collected, recorded and analyzed using standard statistical software (IBM SPSS version 22.0, New York, NY, USA). Bivariate associations between the gender and both sides of SP were evaluated with the Chi-square and Mann—Whitney U tests. Kruskal Wallis and Dunn-Bonferroni post hoc tests were used to determine the association with age. Statistical significance was set at <0.05.

Results

A total of 539 patients (240 males and 299 females) were included in this one year retrospective study. Their mean

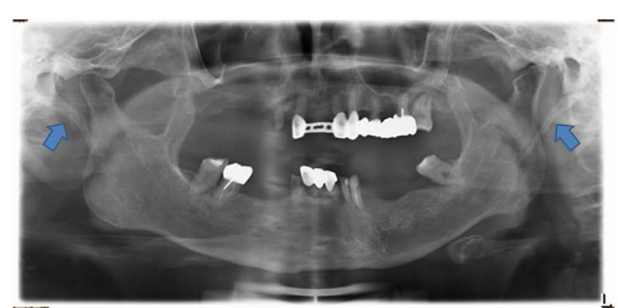

Figure 1 Panoramic radiography is commonly used to measure the length of styloid process (blue arrow) from the tympanic plate to the tip of the process.

of age was 48.2 ± 17.7 years old (range from 18 to 99 years). Their mean SP length was 29 ± 0.7 mm for female and 29.5 ± 0.7 mm for male (Table 1). Measurements were 30 ± 0.7 mm on the right side, and 29 ± 0.7 mm on the left side. Average length on both sides was 29.5 ± 0.7 mm (range from 13.9 to 52.2 mm). Among the general population, the SP equal in length was found in 1.44% (7/486), right > left side was found in 56.17% (273/486), and left > right side was found in 42.39% (230/486). For those patients with symptomatic Eagle syndrome, SP length on their right side was 32 ± 0.8 mm, and on their left side was 33 ± 0.8 mm. Moreover, right > left side was 54.72% (29/53), and left > right side was 45.28% (24/53) (Table 2). Comparisons of SP lengths between gender and across ages are shown in Tables 2 and 3 respectively. No statistically significant difference was found between SP lengths of right versus left side, and for age groups <20 and 21–40 years. More prevalent and longer SP appeared in the age groups of 41–60 years, and in those >60 years (Table 3). SP lengths were clearly longer in older patients, and also longer for patients with symptomatic Eagle syndrome (32.5 ± 0.8 mm) when compared with the general population (29.5 ± 0.7 mm). Finally, the prevalence of elongated SP in our study was 41.5% on the right side, and 36.2% on the left side, and with female predominance (Table 1).

Discussion

The styloid complex includes the SP of the temporal bone, the stylohyoid ligament and the lesser horn of the hyoid bone. Basically, the styloid process is a long cylindrical cartilaginous bone located at the floor of temporal bone. The ligaments attached to the SP are involved in oral functions of mastication and swallowing.[11,21] The elongation of SP and adjacent structures including stylohyoid ligament could directly provoke dysphagia, tinnitus and otalgia that was first described by Italian surgeon Pietro Marchetti (1652) but WW Eagle provide a comprehensive description of the symptoms and known as Eagle's syndrome as well in 1937.[5–7] Elongation of the styloid process is not the main etiology of neck and cervicofacial pain. But most studies agreed on SP's possible compression on nearby neural and vascular structures.[22,23] Symptoms due to elongated SP sometimes are indistinguishable with some disorders like facial neuralgia, or oral and temporomandibular diseases.

Elongated SP can be detected by both physical and radiographic examinations. An unusual palpable SP in the tonsillar fossa indicates the possibility of SP elongation.[21,24] Clinically, palpation of the elongated tip of SP exacerbates painful symptoms, and the elongated SP is typically confirmed by radiographic imaging.[13,19] Orthopanotomographs are the most useful clinical examination in diagnosing bone disorders related to facial structures like in the maxillary, mandibular and TMJ area.[2–4,7,13–16,18,25] It is widely used to determine SP elongation and their ossification such as Kursoglu et al. on Turkish, More & Asrani on Indian, Vieira et al. on Brazilain, AlZarea et al. on Saudian, Gracco et al. on Italian and Anoun et al. on Lebanese population (Table 4). Newly developed CBCT provides a reliable visualization of the orientation and dimensions of the styloid apparatus, but panoramic radiography can further provide realistic images allowing different angulations, and the ease in replicating measurements regarding lengths of the styloid process.[19,20] Our present study is in compliance with experiences of reported studies, and further utilized panoramic images to evaluate the length of SP in a regular and normal bone structure situation.

Previous studies are generally reported the normal SP is approximately 20–30 mm in length. Variations ranged from 16 to 35 mm depending on genetic background or geographic region.[4,7,8,18,26–28] In Japanese population, SP was reported to be 16 mm in length and that report is also the first study on styloid process in Asia regions.[29] Our present study found that in the Taiwanese population, SP measured 30 ± 0.7 mm on the right side, and 29 ± 0.7 mm on the left side. The mean of both sides measured at 29.5 ± 0.7 mm (range from 13.9 to 52.2 cm). That figure almost matched the average length of the styloid process. Our results are similar to those in the Kaufmann study reported in 1970 and AlZarea in 2017.[10,30] Interestingly, our findings of equal SP lengths on both sides being only 1.44%, and the right side being longer than the left side (56.17 vs 42.39%) in the general population. On the other hand, the SP lengths of those patients referred from ENT with symptomatic Eagle syndrome were 32 ± 0.8 mm on the right side and 33 ± 0.8 mm on the left side. These measurements indicated that patients with symptoms showed a tendency of longer SP with statistically significant difference with the general population ($p = 0.001$), particularly on the left side ($p < 0.001$).

The overall elongation of styloid process was postulated to be related to ossification of either the SP or the adjacent stylohyoid ligament.[8,29,31,32] Thresholds of elongated SP varied in the literatures, but in general, measurements >30 mm is considered elongated.[10,14,21,22,27,31,33] The prevalence of styloid process elongation varied greatly across reports, from 3.3% to 84.4% as showed in Table 4.

Table 1 Means length values (mm) of styloid process (SP) in different age groups and across gender from 486 cases in the general population.

Total: 486 panoramic radiographs	Female (n = 272)		Male (n = 214)		*p* value
	Mean	± SD	Mean	± SD	
Age	46.8	±16.8	50.1	±18.6	0.025*
Styloid process (mm)					
Right	29	±0.7	30	±0.7	0.195
Left	29	±0.7	29	±0.7	0.231
Right & Left (Means)	29	±0.7	29.5	±0.7	0.160
Elongation of SP (>30 mm)	No.	%	No.	%	
Right 41.5% (202/486)	109	22.4%	93	19.1%	0.021*
Left 36.2% (176/486)	98	20.1%	78	16.1%	0.024*

Mann–Whitney U test. **p* < 0.05 significantly difference, ***p* < 0.01 more significantly difference.

Table 2 Means length values (mm) of styloid process (SP) length measured on digital panoramic images in different age groups and across gender from 539 cases (including 53 cases with symptoms).

	Styloid process (n = 486)		Eagle syndrome (n = 53)		Total (n = 539)		*p* value
	No.	%	No.	%	No.	%	
Age (mean ± SD)	48.2	±17.7	67.9	±17.8	50.2	±18.6	<0.001**
Sex							0.580
Female	272	(55.97%)	27	(50.94%)	299	(55.47%)	
Male	214	(44.03%)	26	(49.06%)	240	(44.53%)	
Age							<0.001**
Age <20	23	(4.73%)	0	(0.00%)	23	(4.27%)	
Age 21-40	157	(32.30%)	2	(3.77%)	159	(29.50%)	
Age 41-60	181	(37.24%)	19	(35.85%)	200	(37.11%)	
Age >60	125	(25.72%)	32	(60.38%)	157	(29.13)	
Styloid process (mm)	(mean ± SD)		(mean ± SD)				
Right	30	±0.7	32	±0.8	30	±0.7	0.008**
Left	29	±0.7	33	±0.8	29	±0.7	<0.001**
Right & Left (mean)	29.5	±0.7	32.5	±0.8	29.5	±0.7	0.001**
Styloid process		<0.001**					0.646
Right = Left	7	(1.44%)	0	(0.00%)	7	(1.30%)	
Right < Left	206	(42.39%)	24	(45.28%)	230	(42.67%)	
Right > Left	273	(56.17%)	29	(54.72%)	302	(56.03%)	

Chi—Square test. Mann—Whitney U test. **p* < 0.05 significantly difference, ***p* < 0.01 more significantly difference.

Table 3 Means length values (mm) of styloid process (SP) length across different ages in the 539 cases.

Age related factor	Mean	Median	IQR	*p* value	Dunn-Bonferroni post hoc test					
					1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
Styloid process (Right)				<0.001**	0.288	0.004**	0.002**	0.025*	0.010*	1.000
1.Age <20	26 ± 0.7	25	(23—27)							
2.Age 21-40	28 ± 0.7	28	(23—32)							
3.Age 41-60	30 ± 0.7	30	(25—34)							
4.Age >60	30 ± 0.7	30	(26—33)							
Styloid process (Left)				<0.001**	0.182	0.005**	0.001**	0.096	0.005**	1.000
1.Age <20	26 ± 0.7	24	(21—28)							
2.Age 21-40	28 ± 0.7	27	(23—31)							
3.Age 41-60	30 ± 0.7	28	(25—33)							
4.Age >60	30 ± 0.6	29	(27—33)							
Styloid process (mean)				<0.001**	0.178	0.002**	0.001**	0.030*	0.005**	1.000
1.Age <20	26 ± 0.7	24	(22—27)							
2.Age 21-40	28 ± 0.7	27	(23—31)							
3.Age 41-60	30 ± 0.6	29	(25—34)							
4.Age >60	30 ± 0.6	30	(27—33)							

Kruskal Wallis test. **p* < 0.05 significantly difference, ***p* < 0.01 more significantly difference.

Panoramic radiographic assessments revealed elongated SP that varied across populations and ethnic groups. Our findings demonstrate the prevalence of elongated SP was 41.5% (202/486) on right side and 36.2% (176/486) on the left side (Table 1). Our results are similar with those studies of Vieira et al., at 2015 and AlZarea et al., at 2017 but a little lower than the average in other researches.[28,30]

The exact cause of SP elongation is not clear, but cartilaginous calcification and ossification might be due to local chronic irritations related to endocrine disorders (gender-specific), osseous tissue calcification and formation, traumatic mechanical stress and aging.[14,27,30,34,35] Correll (1979) and O'Carroll (1984) reported a significant correlation of SP length with the calcium deposition among 80-year-old patients.[31,36–38] Bozkir (1999) revealed only 4% elongated SP was found in those patients with edentulous ridge.[14] Most reports overlooked the relationship with gender, and only a few reported that clinical symptoms are detected more readily in females. The ratio between female and male had been reported to 1:3.[1,39] Our present study revealed similar findings. In the general population, the elongated SP was 30 ± 0.7 mm in male and 29 ± 0.7 mm in female. But

Table 4 Prevalence of Styloid Process (SP) elongation reported in of previous studies.

Authors	Population	Study Model	Samples	Elongated SP > 30 mm (%)
Eagle[5] (1949)	American	Panoramic	254	4.0
Kaufman et al.[10] (1970)	American	Panoramic	484	28.0
Correll et al.[31] (1979)	American	Panoramic	1771	18.2
O'Carroll et al.[36] (1984)	American	Panoramic	479	78.5
Keur et al.[33] (1986)	Australian	Panoramic	1135	30.0
Monsour & Young[13] (1986)	Australian	Panoramic	670	21.1
Ferrairo et al.[32] (1990)	Italian	Panoramic	286	84.4
Kursoglu et al.[1] (2005)	Turkish	Panoramic	55	83.6
Ilguy et al.[34] (2005, 2013)	Turkish	Pano/CT	860/69	3.7
Gokce et al.[25] (2008)	Turkish	Panoramic	698	7.7
Balcioglu et al.[24] (2009)	Turkish	Pano/skull	227	3.3
Sisman et al.[38] (2009)	Turkish	Panoramic	149	7.7
More & Asrani[2] (2010)	Indian	Panoramic	500	19.4
Bagga et al.[37] (2012)	Indian	Panoramic	2706	79.5 B; 20.5 U
Oztas & Orhan[3] (2012)	Turkish	Panoramic	2000	67.5
Roopashri et al.[7] (2012)	Indian	Panoramic	300	78.5 B; 21.5 U
Vieira et al.[28] (2015)	Brazilian	Panoramic	736	43.89
AlZarea et al.[30] (2017)	Saudi Arabian	Panoramic	198	42.7 R; 52.4 L
Gracco et al.[15] (2017)	Italian	Panoramic	600	33.0
Mathew et al.[35] (2017)	South Indian	Panoramic	100	35.0
Patra et al.[12] (2017)	Indian	Pano/skull	50	10.0
Jamal et al.[16] (2018)	Saudi Arabian	Panoramic	1971	47.8 R; 52.5 L
Asutay et al.[39] (2019)	Turkish	Panoramic	3678	7.01
Hettiarachchi et al.[17] (2019)	Sri Lanka	Panoramic	100	24.6
Sharma et al.[4] (2019)	Nepalese	Panoramic	1061	57.5 R; 42.3 L
Sridevi et al.[18] (2019)	Indian	Panoramic	500	55.8
Aoun et al.[9] (2020)	Lebanese	Panoramic	489	15.5
Rai et al.[8] (2020)	NW Indian	Panoramic	1000	27.3
Chen et al. present study	Taiwanese	Panoramic	539	41.5 R; 36.2 L

females developed SP elongation situations that were easier to observe than males (22.4% vs 19.1% on right side and 20.1% vs 16.0% on left side). Almost 50% of symptomatic patients showed detectable elongated SPs. However, exact anomaly or anatomic variations remain to be identified.

In comparison with other studies, the limitations of our study are not able to consider and analyze the morphology of prolonged SPs because of huge variations attributed to technical reasons such as differences and magnifications of panoramic machine provides, difficulties on digital and manual calibration. Therefore, we have only sufficed to screen for the elongated vs non-elongated processes and compared the relationship between with age, gender and laterality.

The future may be focus on precise measurement the different types of calcification and ossification of styloid process using more advanced imaging technologies.

Based on the findings of our present study, it may be concluded that the mean of SP length in Taiwanese population is 29.5 mm. The mean elongated SP of those with symptomatic Eagle syndrome patients is 32.5 mm, which is longer than the general population. We found no difference between the right and left sides, although such elongation appeared more prevalent and longer in the age groups of 41–60 and > 60 years. Therefore, older patients and patients with symptoms likely have styloid process elongation situations. In addition, the prevalence of elongated SP is 41.5% on the right side and 36.2% on the left side.

Declaration of competing interest

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

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