

## Evaluation of Styloid Process and Its Anatomical Variations: A Digital Panoramic Study with Systematic Review

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ABSTRACT

**Aims and Objectives:** To evaluate the styloid process (SP) and its anatomical variations on digital panoramic radiographs from the database and also to synthesize the current evidence of literature on SP and anatomical variations along with the systematic review of the relevant studies after making the necessary exclusions.

**Materials and Methods:** A total of 500 panoramic radiographs from the database were examined and evaluated for the length of SP using OmniVue software and for the calcification patterns which were categorized into three types as described by Langlais. The obtained values were analyzed using *t*-test and Chi-square tests with a significance level of 0.005 and SPSS version 20.0 software.

**Results and Conclusion:** The mean length of the SP in females was found to be 3.7 cm on the right side and 3.8 cm on the left side. The mean length of the SP in males was found to be 3.4 cm on the right side and 3.3 cm on the left side with significant difference between the genders with the *P* values of 0.0002 and 0.0001, respectively. The length of the SP was significantly longer in females than in males. Type I was the most common SP and was more prevalent in females. The results of the present study along with the wide range of reported incidence of anatomical variations in the form of elongation from the literature extracted through the systematic review suggests the need to reevaluate the range of the normal length of the SP.

**KEYWORDS:** *Calcification patterns, digital panoramic radiograph, styloid process*

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### INTRODUCTION

Styloid process (SP) is a long slender and pointed bony process projecting downward, forward, and slightly medially from the temporal bone. It arises from the temporal bone immediately in relation to the anteromedial aspect of the stylomastoid foramen. It is located between the internal and external carotid arteries and the internal jugular vein, and it is typically straight and occasionally curved.<sup>[1]</sup>

Styloglossus, stylopharyngeus, and stylohyoid are the muscles attached to the SP from the tongue, pharynx, and hyoid bone, respectively.<sup>[2]</sup> The stylohyoid and stylomandibular ligaments extend from the tip of the SP to the lesser cornua of the hyoid bone and to the angle and posterior border of angle of the mandible between masseter and medial pterygoid, respectively.

These ligaments help to regulate the movements of the mandible, the hyoid bone, the tongue, and the pharynx.<sup>[3]</sup>

Many critical anatomic structures such as facial and hypoglossal nerves, occipital artery, internal jugular vein, internal carotid artery, and posterior belly of the digastric muscle are closely located to the SP and the stylohyoid ligament.<sup>[4-7]</sup> The elongation of SP can frequently be encountered by calcification of stylohyoid and stylomandibular ligaments, being the potentially

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triggering factors to precipitate a series of symptoms such as foreign body sensation in the throat, pain on rotating the head, vertigo, dysphagia, odynophagia, facial pain, earache, headache, tinnitus, and trismus, resulting in Eagle syndrome.<sup>[4]</sup> However, majority of the cases are asymptomatic. The normal length of SP is 20–30 mm and is considered to be elongated if it exceeds a length of about 30 mm.<sup>[7,8]</sup>

The studies on the radiological measurements of the SP and its anatomical variations are limited. Hence, the present study was planned to evaluate the anatomical variations of SP in terms of length and pattern of calcifications using digital panoramic radiographs in addition to the systematic review.

## MATERIALS AND METHODS

### SOURCE OF DATA

The study was conducted in the Department of Oral Medicine and Radiology for 9 months. The digital panoramic radiographs acquired with Planmeca 2002 EC Proline Panoramic machine were selected from the database of patients who attended the department for routine dental consultation but not for evaluation of SP and were examined for the length and calcification patterns of SP.

### INCLUSION CRITERIA

- Panoramic radiographs that showed SP on both right and left sides
- Relevant published articles in English language on SP and anatomical variations using digital panoramic radiographs.

### EXCLUSION CRITERIA

- Panoramic radiographs depicting incomplete SP or only on the one side
- Panoramic radiographs that showed errors such as size and shape distortion
- Panoramic radiographs that were taken for the evaluation of the SP
- Articles published in the language other than English.

### METHODOLOGY

The digital panoramic radiographs from the database made using Planmeca 2002 EC Proline Panoramic machine were retrospectively examined through simple randomization for the presence and bilaterally measurable SP without magnification errors, considering the magnification factor of the machine as 1.22. The demographic and clinical data were obtained from the records and radiographs of those depicting any history of trauma or symptoms that could be attributed to elongated SP such as pain on turning the head, feeling of the presence of foreign object in the throat were further

excluded from the study. The 500 digital panoramic radiographs (250 males and 250 females) meeting the inclusion and exclusion criteria were selected and used to measure the length of the SP by two experienced radiologists. The study protocol was approved by the institutional ethical committee with the Ref No. of File No. 116/IEC/LIDS/2018, and informed consent was obtained from the participants for using the digital radiographic data.

The length of SP was measured as the distance from the point where SP leaves the tympanic plate of temporal bone to the tip of SP as described by Langlais<sup>[8]</sup> using Omni-View software, Version 3.1, Genesis Digital Imaging which is a fully FDA (Food and Drug administration) compliant & DICOM (Digital Imaging and Communications in Medicine) compatible. The length was measured in values of points and then converted into centimeters (cm) [Figure 1] using Kyle's converter. The length of SP that exceeds 3 cm was considered to be elongated.

The calcification pattern of SP on both right and left sides were recorded as described by Langlais into following three types:

- Type I: SP showing calcified outline [Figure 2a]
- Type II: Mineralized stylohyoid or stylomandibular ligaments attached to SP by a single pseudoarticulation [Figure 2b]
- Type III: Segmented SP containing multiple pseudoarticulations [Figure 2c].

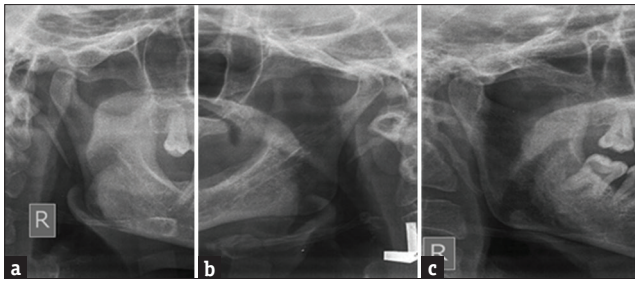
### STATISTICAL ANALYSIS

The values in centimeters were tabulated and statistically analyzed with SPSS version 20.0 software (IBM, Chicago, USA). *t*-test and Chi-square tests were used for the analysis and a significance level of 0.005 was considered for comparisons between the groups.

The systematic review was carried out by tracking the publications in English language using search engines namely PubMed and MeSH with no time limit for relevant articles for distinctive terms: styloid process, anatomical variations, panoramic and digital panoramic



Figure 1: Measurements of the styloid process through the digital OPG



**Figure 2:** (a) Type I styloid process showing calcified outline, (b) Type II styloid process, (c) Type III segmented styloid process

in different combinations. Two independent reviewers conducted all levels of screening, data abstraction, and quality appraisal.

## RESULTS

From the 500 panoramic radiographs of the database, 250 were of males and 250 were of females with a mean age of 38 years and 41.4 years, respectively, as depicted in Table 1. The kappa coefficient was 0.89 and reflected an excellent degree of interobserver agreement. The mean length of SP in females was 3.7 cm on the right side and 3.8 cm on the left side, whereas the mean in males was 3.4 cm on the right side and 3.3 cm on the left side as shown in Table 2. The length of the SP was significantly longer in females than in males on both right and left sides with the  $P = 0.0002$  and  $0.0001$ , respectively [Table 2]. However, the difference was not statistically significant between the sides of the same gender in both males and females ( $P = 0.1629$  and  $0.4618$ ).

Of the total sample, 279 radiographs, i.e., 55.8%, were observed to have bilaterally elongated SP of which females constituted 33.2% and males constituted about 22.6%. Unilaterally elongated SP was observed on 125 radiographs, i.e., 25.5% of the total sample, of which 11% were female and 14% were male and 19.2% showed the length measuring 3 cm or <30 cm [Table 3]. In males, the maximum length of SP was on the right side and was 6.9 cm, whereas in females, the maximum length was on both sides and was 7.9 cm.

Both the genders showed Type I as the most common type of calcification followed by Type II and Type III. Of the females, 89.9% showed Type I, 9.3% of Type II, and 0.8% of type III were observed on the left side and 84.7% of Type I, 13.7% of Type II, and 1.6% of Type III were observed on the right side. Of all males, 91.3% of Type I, 8.7% of Type II, and 0% of type III were observed on the left side and 86% of Type I, 13.7% of Type II, and 0.4% of Type III were observed on the right side as shown in Table 4.

**Table 1: Depiction of age and distribution of the sample**

Gender (sample size)	Range	Mean±SD
Males (250)	21-61	41.4±10.2
Females (250)	18-70	38.0±9.0

SD=Standard deviation

**Table 2: Measurements of the styloid process**

Anatomical site	Gender				P
	Male		Female		
	Range	Mean±SD	Range	Mean±SD	
Right side	1.3-5.7	3.4±0.8	1.1-5.9	3.7±1.0	0.0002
Left side	1.6-5.5	3.3±0.8	1.4-7.9	3.8±1.9	0.0001
P	0.1629		0.4618		

SD=Standard deviation

**Table 3: Distribution of the length of the styloid process among the sample**

Gender	SP		
	Measuring <3 cm (96; 19.2%)	Measuring >3 cm (404; 80.8%)	
		Unilateral (125; 25%)	Bilateral (279; 55.8%)
Males	54 (10.8)	70 (14)	113 (22.6)
Females	42 (8.4)	55 (11)	156 (33.2)

SP=Styloid process

**Table 4: Patterns of calcification**

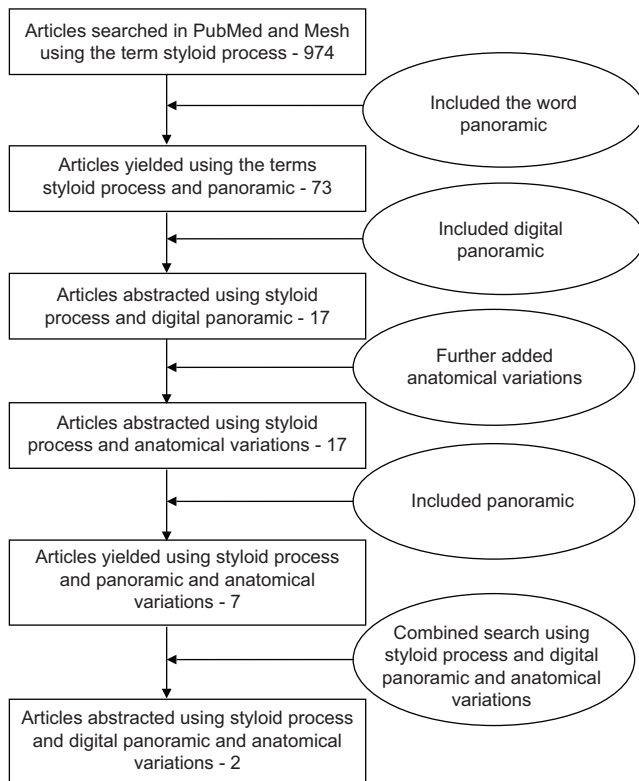
Type	Gender (%)			
	Male		Female	
	Right side	Left side	Right side	Left side
Type I	86	91.3	84.7	89.9
Type II	13.7	8.7	13.7	9.3
Type III	0.4	0	1.6	0.8

The tracking of the publications in English language using PubMed and Mesh as search engines by two researchers independently for the term SP yielded 974 articles and by adding the word panoramic yielded 73 articles. Addition of terms digital panoramic and anatomical variations separately to SP yielded 17 articles each. Seven articles were abstracted for the combined search of SP and panoramic and anatomical variations. Finally, only two articles could be extracted through the summative search of SP and digital panoramic and anatomical variations [Flowchart 1], while two independent reviewers conducted all levels of screening, data abstraction, and quality appraisal.

## DISCUSSION

The SP gains importance in health care for being its proximity to most of vital structures in the vicinity such as the facial and glossopharyngeal nerves, occipital artery, internal jugular vein, internal carotid artery, and posterior belly of the digastric muscle. The elongated





**Flowchart 1:** Depiction of search protocol for the systematic review

SP is considered to be the result of ossification of the stylohyoid ligament or the SP.<sup>[9]</sup> There are many suggested hypotheses regarding the etiology of elongation of SP that include theories of reactive hyperplasia, reactive metaplasia, anatomic variance, aging developmental anomaly, degenerative process, and genetic hypothesis. Despite many suggested hypotheses, the exact etiology still remains unknown.<sup>[10]</sup>

The SP may exhibit anatomical variations that differ from person to person and population to population and could be better visualized on panoramic radiographs.<sup>[11-15]</sup> However, the other approaches to determine the dimensions of SP include the lateral cephalograms, lateral views of neck, posterior-anterior views of skull, computed tomograms, and cone-beam computed tomograms. Although different studies on the dimensions of SP were based on dry skulls and cadavers, the use of digital panoramic radiographs can be considered as preferred method for the evaluation of the SP as it is a simple technique of routine use in dental health care setups.

In the present study, initially, 974 articles could be extracted through PubMed and MeSH in English language and applying the key phrases we could observe drop in the number to 17 which could be because of the extraction of the articles also related to the ulnar SP. In this systematic review, the use of the key phrase digital

panoramic radiographs further abated to seven and this was because most of the reports were focused on case reports and reviews. After criteria selection of the key phrase of SP, anatomical variations, digital panoramic radiograph, and cross-referencing, two studies by Vieira *et al.*<sup>[12]</sup> and Hettiarachchi *et al.*<sup>[13]</sup> could be abstracted as one of the primary outcomes of the present study for the systematic review, and hence, we further considered the articles related to our study. To the best of our knowledge, this is the first systematic review published on the evaluation of SP and its anatomical variations through digital panoramic study.

Although, most of the times, the anatomical variations such as elongation are asymptomatic, sometimes may lead to a series of symptoms such as foreign body sensation in the throat, pain on rotating the head, vertigo, dysphagia, odynophagia, facial pain, earache, headache, tinnitus, and trismus, resulting in Eagle syndrome. It can also cause vertigo, tinnitus, dysphonia, carotidynia, and reduced mandibular opening and may be misinterpreted as temporomandibular disorders (TMDs), tumors of tongue base, trigeminal and glossopharyngeal neuralgia, migraine, unerupted third molars, myofascial pain, hypersalivation, and even alteration in taste many at times mandating to be included under the differential diagnosis. Hence, it is an important aspect to be taken into consideration to evaluate, diagnose, as well as treat the condition with mere expertise.

In India, 19.4%–52.1% of the general population was found to have the radiographic evidence of an elongated SP, the highest (52.1%) being recorded in the region of Mathura (North India)<sup>[12]</sup> although Ilgüy *et al.*<sup>[16]</sup> reported an incidence of 3.7%. As another primary outcome, in the present study, 80.8% of the population showed anatomical variation of SP in the form of elongation, and to our surprise, none of them had a recorded history of symptoms related to the same. The overall reported incidence of elongation of SP was widely varied from 1.4 to 83.6%<sup>[3,5,12-18]</sup> [Table 5]. The lower incidence was reported by Ilgüy *et al.* as 3.7% and Eagle as 4%. However, Correll *et al.*<sup>[19]</sup> observed elongation in 18.2%, Monsour and Young *et al.* in 21.1%,<sup>[17]</sup> Alpoz *et al.* in 27.1% as calcified stylohyoid ligament,<sup>[18]</sup> Vieira *et al.* in 43.89%,<sup>[12]</sup> and Hettiarachchi *et al.* in 59.5%<sup>[13]</sup> of their sample. Although a higher incidence of elongation was observed in the present study, it is in consistent with previous reports. This wide variation in the observations in studies conducted in different locations could be due to variations in the diagnostic and interpretation tools and criteria, geographic location, local population particularities, and sizes of the sample.

**Table 5: Summary of the reported studies with salient features**

Author	Year	Country	Sample	Age (years), range and mean±SD	Mean length of the SP (mm)				Elongation and common calcification types
					Female		Male		
					Right	Left	Right	Left	
Hettiarachchi <i>et al.</i> <sup>[13]</sup>	2019	Sri Lanka	100 digital panoramic images	20-30 Males: 24.7 Females: 25.4	25.8±4.4	24.8±5.5	28.4±6.2	26.4±5.4	Males: 34.9% Females: 24.6% Type I (55%) Bilateral: 11 of 29; unilateral: 18 of 29 Total: 43.89% Male: 18.35% Female: 25.54% (female > male)
Vieira <i>et al.</i> <sup>[12]</sup>	2015	Brazil	736 digital panoramic images	35					
Vadgaonkar <i>et al.</i> <sup>[3]</sup>	2015	India	110 human dried skulls		On right side: 17.8±9.3 (gender not specified) On left side: 18.2±5.6				
Alpoz E <i>et al.</i> <sup>[18]</sup>	2013	Turkey	1600	18-89, 40.18±15.41	12 patterns				Calcified stylohyoid ligament: 27.1%

SP=Styloid process, SD=Standard deviation

The mean age of males in the present study was 38 years and it was 41.4 years in females. Hettiarachchi *et al.*<sup>[13]</sup> reported the mean age as 24.7 years in males and 25.4 in females similar to our study regarding the fact that the females are elder to males whereas the other reports state the mean age as 35 years<sup>[12]</sup> and 40.18 ± 15.41.<sup>[18]</sup>

The exact mechanism of calcification and elongation of SP is not fully understood though attributed to various hypothetic theories such as the theory of reactive hyperplasia, theory of reactive metaplasia, and theory of anatomic variance.<sup>[20]</sup> According to Steinmann,<sup>[20]</sup> theory of anatomic variance suggests that the early elongation of the SP and calcification of the stylohyoid ligament are normally calcified and that the elongation of the SP is an anatomic variation and that could be detected on the radiographs. According to the hypothetic theory of aging developmental anomaly, the soft cervical tissues lose their elasticity and age. As a result, the increased resistance to movement of the joint between the stylohyoid ligament and lesser horn of the hyoid bone can cause secondary tendinitis in elderly people, leading to subsequent calcification and cause symptoms. The increase in the length of the SP in the present study with respect to the normal range could be related to the hypothetic theory of anatomic variance as we included the radiographs of asymptomatic sample.

In the present study, the mean length of the SP in females (3.7 on the right side and 3.8 on the left side) was found to be higher than that of males (3.4 on the right side and 3.3 on the left side) which was in accordance with the studies conducted by Lins *et al.*<sup>[21]</sup> and Joshi and Iyengar<sup>[22]</sup> and in variance with the other studies<sup>[5,13]</sup> [Table 5]. This could be due to methods used for the measurement of SP in various studies<sup>[14,23,24]</sup> such as the use of rulers and vernier calipers directly on radiographs and digital calipers and very few studies

that used digital radiographs. However, in the present study, we measured the length in values of points using OmniVue software as point is any smallest measure that could be obtained on a digital image [Figure 1]. The obtained values in points were converted into centimeters using Kyle's converter.

The mean length of SP in both the genders was observed to be greater on the right side than left side which was in accordance to the reports by Balcioglu *et al.*<sup>[5]</sup> Hettiarachchi *et al.*<sup>[13]</sup> and Correll *et al.*<sup>[19]</sup> These findings are in contrast to the study by Joshi and Iyengar<sup>[22]</sup> where the mean length was greater on the left side than on the right side. However, the difference in reported studies including our study ( $P = 0.1629$  and  $0.4618$ ) was not statistically significant between the sides in both males and females. Although most of the previous reports state that the normal SP measures 25–30 mm and is considered as elongated if it measures >30 mm, Jung *et al.*<sup>[25]</sup> evaluated 1000 panoramic radiographs of normal population and proposed that SP be considered elongated on panoramic radiograph only if its length exceeds 45 mm. The mean length of the SP in the present study was also found to be >30 mm.

In our study, females (201) predominated over males (183) and the difference was found to be statistically significant [ $P = 0.0002$  and  $0.0001$ , Table 2] in accordance with the previous reports by Vieira *et al.*<sup>[12]</sup> and Ilgüy *et al.*<sup>[16]</sup> though in contrary to the report by Hettiarachchi *et al.*<sup>[13]</sup> Unlike our study, these reported predominances were found to be statistically insignificant. The other contributing factor for the insignificant result may be variation in the sample size of the genders. Males predominated the unilateral elongation of SP whereas the females predominated the bilateral elongation of SP. The elongation is usually bilateral which was evidenced in our study by the observation

that 55.8% of the digital panoramic radiographs showed bilateral involvement [Table 3]. However, Correll *et al.* reported that 93.4% of the patients in their study were presented with bilateral involvement<sup>[19]</sup> and Lins *et al.* reported that 85% of their sample showed bilaterally elongated SP.<sup>[21]</sup> The discrepancies in the results may be attributed to the differences in the population; their ethnic origin studied and image acquisition and interpretation criteria. In the present study, the calcification patterns of elongated SP were categorized according to the classification proposed by Langlais *et al.*<sup>[8]</sup> based on the radiographical features; Type I could be depicted on the radiographs as uninterrupted integrity of the stylohyoid complex regardless of its length [Figure 2a]. In Type II, the SP is apparently joined to the mineralized stylomandibular or stylohyoid ligament by a single pseudoarticulation [Figure 2b], whereas Type III comprises either short or long noncontinuous positions of the styloid complex or interrupted segments of mineralized styloid ligament [Figure 2c]. It was observed that Type I SP was more common in males and females on both right and left sides which was in correlation with most of the previous studies<sup>[13,14,16,21]</sup> followed by Type II and III.

From the observations of the study and the reviewing the literature, it can be suggested that the mere elongated SP, i.e., measuring >30 mm, does not necessarily confirm the diagnosis of Eagle syndrome as none of our cases experience the symptoms although the mean length is greater than 3 cm. Although an elongated process is found bilaterally, patients can typically display unilateral symptoms. Reviewing and reevaluation of the normal range of length of the SP should be considered, and systematic reviews in this regard may be encouraged.

## CONCLUSION

The present study contributes to the knowledge regarding the radiographic evaluation of the SP and its anatomical variations with the systematic review. The length of the SP was significantly longer in females than in males. Type I was the most common SP and was more prevalent in females. The observations from the present study and the inclusion of those advised radiographs for neither the evaluation of the SP nor the symptoms related to elongation suggest that all SPs measuring greater than 30 mm do not necessarily lead to symptoms which were to be considered among the differential diagnoses of orofacial pain, neuralgias, and other maxillofacial pathologies in order not to override into a misdiagnosis. Owing to the wide range of incidence of anatomical variations in the form of elongation, further studies with considerably larger sample among different populations of different ethnic origin with advanced

evaluation/diagnostic methods may explore the need to reevaluate the range of normal length of the SP.

## LIMITATIONS

To the best of our knowledge, this is the first systematic review on SP and its anatomical variations and has the potential to reevaluate the normal length of the SP. However, literature may have been missed by the search or misclassified because of incomplete reporting. Validity and reliability testing of authors' recommendations are required.

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## CONFLICTS OF INTEREST

There are no conflicts of interest.

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