Original Article

Length of the styloid process associated with different skeletal patterns in Turkish Adolescents

ABSTRACT

Aim: The purpose of this study was to investigate the length of the styloid process (SP) in different skeletal patterns and stages of skeletal maturation.

Materials and Methods: Radiographs involving SP (n = 158; 77 female and 81 male, age with a mean value of 12.84 ± 1.94 years) were evaluated retrospectively. Class I group included 52 subjects (0 ≤ ANB ≤4), Class II group included 57 subjects (ANB>4), and Class III group included 49 subjects (ANB < 0). The length of the SP was measured in Photoshop CS5 software (Adobe Systems Inc., San Jose, CA, USA). Skeletal maturation stages were determined by the evaluation of hand-wrist radiographs and lateral cephalometric radiographs. The data were analyzed using Student's t-test and one-way ANOVA.

Results: Statistically significant difference in the length of the SP was found between Class I and Class II group ($P \leq 05$). The mean length of the SP was 30.68 ± 9.69 mm in Class I group and 34.63 ± 5.87 mm in Class II group. No statistically significant difference was found in between skeletal maturation stages of the groups neither in the bilateral length of the SP between genders.

Conclusion: The risk of Eagle syndrome in skeletal Class II malocclusion might be higher. In addition, when a patient is referred with pain in the temporomandibular area with skeletal Class II anomaly, SP elongation should be considered besides the joint problems.

Keywords: Panoramic radiograph, skeletal malocclusion, skeletal maturation, styloid process

INTRODUCTION

The styloid process (SP) is a cylindrical bone located in front of the stylomastoid foramen on the temporal bone [Figure 1]. The proximal part joins the tympanic plate, allowing it to ligate to distal muscles and ligaments such as the stylopharyngeus, styloglossus, and stylohyoid muscles and stylomandibular and stylohyoid ligaments.[1] SP anomalies might be encountered in several cases. The SP is formed by Reichert's cartilage originating from the second branchial line.[2] According to Lentini, the residues of these embryological tissues originating from the SP can induce osseous metaplasia and anomalies with a surgical trauma.[3] SP might consist of stylohyal, tympanohyal, ceratohyal, and hypohyal parts by the degeneration of the Reichert's cartilage. The tympanohyal part is calcified at birth; however, it is considered to attach to the temporal bone approximately at 1 year of age. The stylohyal part is formed after birth and gradually becomes calcified. The calcification of the stylohyal part might result in elongated SP (ESP). Ceratohyal and hypohyal cartilage transform into the styloid ligament in the prenatal period. Occasionally, if there is calcification in the ceratohyal cartilage but not in the stylohyal cartilage, fragmented SP might occur.[4] Elongation of the SP is also thought to be possibly related to the styloid ligament. The styloid ligament is the connective tissue band originating

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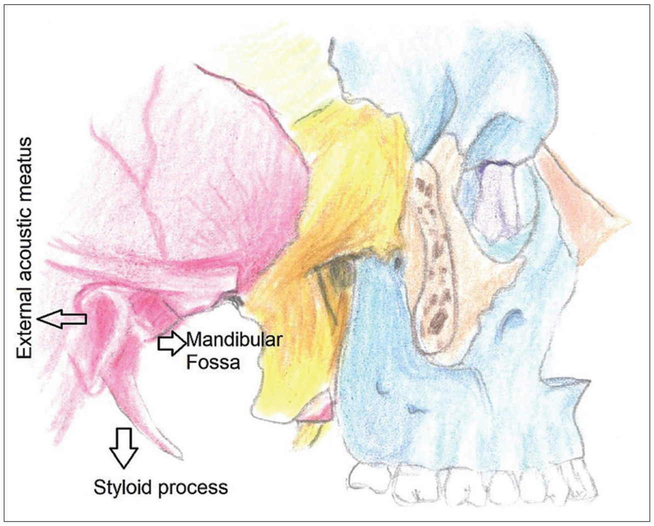

Figure 1: The styloid process location on the skull

from the apex of the SP which sticks to the lesser horn of the hyoid bone. The cartilage content of the ligament can result in ossifications at different grades. Calcium deposits at the tip of the SP may cause elongation.[5,6]

The SP is considered to be ESP when the length exceeds 30 mm.[6] Symptoms occurring as a result of ESP are associated with the anatomical structures around the SP. These symptoms and findings are thought to be the result of pressure on the neural and vascular structures surrounding the SP. The cause of ESP is unknown.[7,8] According to Eagle, surgical traumas such as tonsillectomy, chronic irritation of the stylomandibular ligament, or osteitis of the SP can result in ESP.[9] ESP associated with symptoms such as dysphagia, odynophagia, otalgia, tinnitus, trismus, headache, and facial pain is described as Eagle syndrome.[10]

The length of the SP increases with age.[11] The assessment of chronological age alone is not sufficient to assess developmental progression, especially in adolescence.[12] The assessment of skeletal maturation provides more detailed information on the timing and magnitude of the growth.[13] In a clinical setting, lateral cephalometric and hand-wrist radiographs are readily available and can be used as a reliable and efficient technique for developmental assessment.[14,15]

No study has assessed the relationship between the SP and different skeletal malocclusions and skeletal maturation. The purpose of this study was to investigate the length of the SP in skeletal Class I, II, and III anomalies [Figure 2] and to identify the change in the length of the SP between the skeletal maturation phases obtained from the evaluation of the hand-wrist and lateral cephalometric radiographs. The null hypothesis assumed that there was no difference in the length of the SP between the skeletal maturation phases determined by the evaluation of the hand-wrist radiographs (1) and lateral cephalometric radiographs (2), in the length of the SP in skeletal Class I, II, and III anomalies (3), and between the genders (4) in terms of the SP length.

MATERIALS AND METHODS

The study protocol was approved by the Ethics Committee of the Clinical Research, Kırıkkale University. The single-center, single-blinded retrospective study evaluated pretreatment panoramic, lateral cephalometric, and hand-wrist radiographs of individuals who had visited the Orthodontic Department of Dentistry of Kırıkkale University between November 2012 and January 2017.

Radiographs of 986 individuals without any complaints affecting growth and development, any missing teeth, any malformation in the handwrist, cervical vertebra, and craniofacial system were examined. One hundred and fifty-eight radiographs with the SP were evaluated. The panoramic, lateral cephalometric, and hand-wrist radiographs were taken using a Kodak digital 9000 panoramic unit (Carestream Health, Rochester, NY, USA). Panoramic radiographs were taken under standard conditions using a cephalostat with the clinical Frankfort horizontal plane (FHP) and mid-facial planes corrected. The FHP was set parallel to the ground plane and perpendicular to the mid-facial plane. All radiographs were taken on the same day with the same device. Measurements were made bilaterally to avoid magnification errors. Measurements were carried out by a single experienced observer to minimize the measurement errors. To determine the measurement accuracy of the observer, 30 randomly selected radiographs were re-evaluated 4 weeks following the measurements.

On panoramic radiographs, the distance from the base of the temporal bone to the tip of the SP was measured to find the closest value to the actual length of the SP.[16,17] This view of SP is difficult to identify on every radiograph due to the superposition; only the radiographs involving that view were taken into consideration.

The SP length was measured bilaterally. Measurements were made via the ruler function in Photoshop CS5 software (Adobe Systems Inc., San Jose, CA, USA).

One hundred and fifty-eight subjects (77 female, 81 male, with a mean age of 12.84 ± 1.94 years, between 9 and 18 ages) were

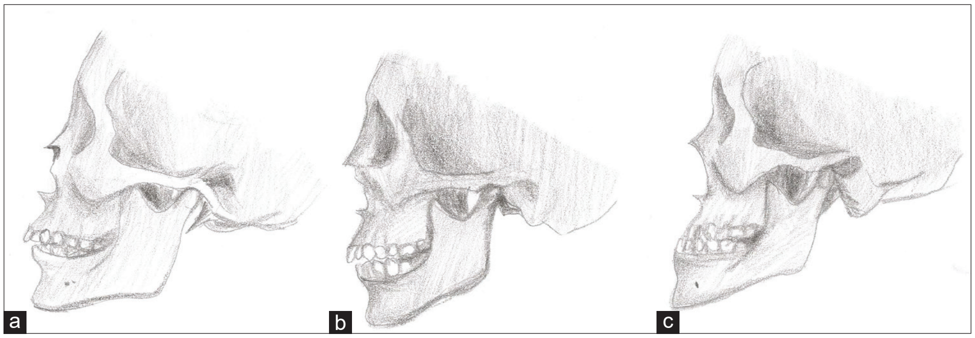

Figure 2: (a) Skeletal Class I, (b) Skeletal Class II, (c) Skeletal Class III

evaluated. Class I group included 52 subjects (0 ≤ ANB ≤ 4), Class II group included 57 subjects (ANB>4), and Class III group included 49 subjects (ANB<0).

The skeletal maturation stage of each hand-wrist radiograph was evaluated according to the method described by Björk[14] and Grave and Brown[18] (BGB method) [Table 1]. They were categorized into three groups;

Group 1: Prespurt-BGB: Stage 1, Stage 2, and Stage 3 (n = 37)
Group 2: Spurt-BGB: Stage 4, Stage 5, and Stage 6 (n = 52)
Group 3: Postspurt-BGB: Stage 7, Stage 8, and Stage 9 (n = 69).

Cervical vertebral maturation (CVM) was determined using Hassel and Farman[15] method, which assess maturational changes on the second, third, and fourth cervical vertebrae [Table 2]. The subjects were categorized according to their CVM into two groups;

Group 1: Prespurt-CVM: Stage 1, Stage 2, and Stage 3 (n = 55)
Group 2: Postspurt-CVM: Stage 4, Stage 5, and Stage 6 (n = 103).

Statistical analysis

All data were analyzed using the SPSS software program, version 20.0 (IBM SPSS Statistics for Windows; IBM Co., Armonk, NY, USA). Data were tested for normality using Shapiro–Wilk test.

The Student's t-test was used to determine whether there was a statistically significant difference between male and female. Differences between skeletal groups and differences between skeletal maturation (determined by hand-wrist radiographs) were analyzed using one-way ANOVA and followed by *post hoc* Tukey HSD method. Differences between skeletal maturation (determined by cervical vertebrae) were analyzed using Student's t-test.

A paired t-test was performed to determine whether there was a statistically difference between the left and right measurements on the panoramic radiographs, and the similarity between both the sides was evaluated with the Pearson correlation test.

Intraexaminer reliability was determined by selecting 10 random subjects representing each skeletal group (30 radiographs)

Table 1: Skeletal maturation of each hand-wrist radiograph according to method of Björk and Grave and Brown

Stage 1 (PP2=): The width of the epiphysis of the proximal phalanx of the second finger is equal to the diaphysis width
Stage 2 (MP3=): The epiphyseal width of the middle phalanx of the third finger is equal to the diaphysis width
Stage 3 (Pisi=, R=, H1): The ossification of Psiform bone, R=The epiphyseal width of the radius is equal to the diaphysis width, H1=The hamate hook becomes prominent
Stage 4 (S, H2): Sesamoid bone ossification occurs, H2=The hamate hooks becomes more prominent
Stage 5 (MP3 cap, PP1cap, Rcap): Epiphyseal capping on the middle phalanx of the third finger, PP1cap=Capping on the proximal phalanx of the thumb, Rcap=Capping on the radius are observed
Stage 6 (DP3u): The epiphysis and diaphysis of the distal phalanx of the third finger fuse
Stage 7 (PP3u): The epiphysis and diaphysis of the proxymal phalanx of the third finger fuse
Stage 8 (MP3u): The epiphysis and diaphysis of the middle phalanx of the third finger fuse
Stage 9 (Ru): The epiphysis and diaphysis of the radius fuse

Table 2: Skeletal maturation of each lateral cephalometric radiograph according to Hassel and Farman

Stage 1: Vertebrae are wedge shaped, and the superior vertebral borders were tapered from posterior to anterior
Stage 2: Concavities are developing in the inferior borders of C2 and C3. The inferior border of C4 was flat. The bodies of C3 and C4 were nearly rectangular in shape
Stage 3: Distinct concavities are seen in the inferior borders of C2 and C3. A concavity was beginning to develop in the inferior border of C4. The bodies of C3 and C4 were rectangular in shape
Stage 4: Distinct concavities are seen in the inferior borders of C2, C3, and C4. The vertebral bodies of C3 and C4 nearly square
Stage 5: Accentuated concavities are seen in the inferior borders of C2, C3, and C4. The bodies of C3 and C4 are nearly square in shape
Stage 6: Deep concavities are seen in the inferior borders of C2, C3, and C4. The bodies of C3 and C4 are square ora re greater in vertical dimension than in horizontal dimension

C: Cervical vertebrae

for a second measurement. Intercorrelation coefficients were calculated for the measurements to test intraexaminer variability. $P \leq 0.05$ was considered statistically significant.

RESULTS

Intraexaminer correlation coefficient indicated high reliability between two measurements ($r = 0.98$). No statistically significant difference was found between the length of the SP in females and males ($P > 0.05$). Correlation between the right and left sides was high for SP measurements ($r = 0.86$; $P < 0.001$) without significant difference ($P > 0.05$). For this reason, the mean of the right and left sides was used in all statistical analyses.

The evaluation of SP via panoramic and skeletal malocclusion was performed via lateral cephalometric radiographs; There was a statistically significant difference between skeletal Class I and II groups ($P \leq 05$); however, no statistically significant difference was found between Class I and Class III and between Class II and Class III groups ($P > 0.05$) [Table 3].

The evaluation of SP via panoramic and skeletal maturation was performed via hand-wrist radiographs; intergroup (prespurt-BGB, spurt-BGB, and postspurt-BGB) comparisons revealed no statistically significant difference ($P > 0.05$) [Table 4].

The evaluation of SP via panoramic and skeletal maturation was performed via lateral cephalometric radiographs; intergroup (prespurt-CVM and postspurt-CVM) analysis showed no statistically significant difference ($P > 0.05$) [Table 4].

DISCUSSION

The length of the SP was found approximately 20–30 mm.[19] The increase in the SP length is occasionally important in the clinical aspect. As the SP is surrounded by neural and vascular structures, the ESP exerts pressure on these structures resulting in pain which can be confused with the pain resulting from oral or dental diseases, temporomandibular joint disorders, and facial neuralgia.[20] Thus, studies focusing on the SP have gained attention.

The graphs of developing individuals with age between 9 and 18 years have been evaluated. The SP usually ossifies 5–8 years after birth.[5] Contrary to the studies in which the SP length was reported to increase over time,[11] there are studies that declared the SP length to be unchanged.[20] Considering skeletal age rather than chronological age would be a better approach in determining skeletal maturation.[12] No significant correlation was found between skeletal maturation phases and the SP length evaluated via hand-wrist and lateral cephalometric radiography in growing individuals. Thus, the first and second null hypotheses were accepted. In the literature, there is no other study investigated whether SP length is affected by skeletal maturation. Therefore, it would be beneficial to conduct studies with groups classified according to the skeletal maturation phases, homogeneous intergroup distribution, and adequate sample size.

In line with our findings, there are studies which found no statistically significant difference between genders in terms of the SP length.[2,19] Thus, the fourth null hypothesis was accepted. Nevertheless, the SP length was also reported to differ between genders.[4] This difference might result from ethnic diversity.

The length of the SP was found to be different in Skeletal Class I, II, and III malocclusions. This difference was identified to arise from skeletal Class I and Class II malocclusions. The SP length in Class II subjects was significantly higher. Thus, the third null hypothesis was partially rejected. Conditions that might result in ESP are as follows: SP consists of four parts, one of which is the

Table 3: The length of styloid process for skeletal patterns

	Mean±SD			ANOVA	Tukey's HSD		
	Class I group (n=52)	Class II group (n=57)	Class III group (n=49)	P	I-II	I-III	II-III
Length of styloid process	30.68±9.69	34.63±5.87	31.59±13.20	0.05*	0.05*	0.69	0.25

*Significant at $P \leq 0.05$. HSD: Honestly significant difference, SD: Standard deviation

Table 4: The length of styloid process for skeletal maturation stages

	Mean±SD			P
	Prespurt-BGB (n=57)	Spurt-BGB (n=52)	Postspurt-BGB (n=69)	
Length of styloid process	29.19±8.85	33.87±11.37	33.27±9.05	0.063
	Mean±SD			P
	Prespurt-CVM (n=55)		Postspurt-CVM (n=103)	
Length of styloid process	31.64±12.40		32.98±8.38	0.476

SD: Standard deviation, CVM: Cervical vertebrae maturation, BGB: Björk, Grave and Brown stylohyal, in intrauterine life. The SP elongation might stem from an excess of calcification in this part.[4] Class II individuals may have an anatomical variation resulting from excessive calcification of this section.

Elongation of the SP is thought to be associated with the styloid ligament. Styloid ligament is the connective tissue band originating from the apex of the SP and adheres to the lesser horn of the hyoid bone.[4] Due to the cartilage content of the ligament, ossifications at different degrees might occur. Calcium deposits at the tip of the SP may cause elongation.[5] Sloan *et al*. found that the location of the hyoid bone was superior and anterior to the mandible in the Class I malocclusion and inferior and posterior to the mandibula in the Class II malocclusion.[21] This difference might have led to the formation of a longer SP in Class II individuals.

The functions of stylopharyngeus, m. stylohyoideus, and m. styloglossus might make a change in the length of SP.[11] The SP is connected to the tongue with the styloglossus muscle, to the pharynx with stylopharyngeus muscle, to the hyoid bone with the stylohyoideus muscle/ligament, and to the mandible with the stylomandibular ligament. Among Class I and II individuals, the position of the mandible,[21] the position of the hyoid bone,[21,22] the position of the tongue,[23] the pharyngeal airway dimensions,[24] and the chewing activity[25] vary. Therefore, a change in the SP length might have been observed between these groups.

The difference in the SP length was expected to exist between Class I and Class III individuals; however, no statistically significant difference was obtained. This finding might be a result of not considering the origin of the malocclusion, a factor that can be counted as a limitation of our study. Class II and Class III anomalies can be caused by the problems of upper jaw, lower jaw, or both.[26] This information should be taken into account when designing new studies.

Panoramic, lateral cephalometric, Towne's view, posteroanterior radiographs, and three-dimensional imaging techniques can be used to determine the SP length.[27] The reliability of dimensional measurements in panoramic radiographs is debated, especially because of the magnification and distortion problems. Therefore, to minimize the magnification difference, radiographs were taken with a standard head position perpendicular to the mid-facial plane and parallel to Frankfurt's horizontal plane.[28] In addition, Larheim and Svanaes[29] showed that reproducibility was significantly higher in the panoramic view. Moreover, Vaishali *et al*.[30] showed that the dimensional measurements were very close to the actual values in the panoramic view. Evaluations can also be made via three-dimensional images;[8] however, they are less preferable due to the high cost and radiation dose.[27]

The length of the SP is usually measured by calculating the distance between the points where SP leaves the tympanic plate of the temporal bone and the bony tip of SP.[1] In our study, the length was calculated by measuring the distance between the tip and the point where SP originates from the base of the temporal bone to determine the closest value to the anatomical length. Since measuring the SP length was challenging in radiographs due to the superposition, the number of evaluated radiographs was highly limited.

CONCLUSION

1. SP length is not affected by skeletal maturation in growing individuals
2. The length of the SP differs between skeletal Class I and Class II individuals. Thus, panoramic radiographs must be carefully evaluated for SP in patients with Class II skeletal patterns. It should be taken into consideration that the risk of Eagle syndrome in skeletal Class II malocclusion may be higher
3. In addition, when a patient was referred with pain in temporomandibular joint syndrom area with skeletal Class II abnormality not only joint problem but also the SP elongation should be considered
4. The limitation of our study is the use of two-deimensional radiography. It would be helpful to use three dimensions that can evaluate the actual length of SP
5. It would be probably better to increase the number of subjects. Further studies on SP in different skeletal patterns and the factors related to its etiology are needed.

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Conflicts of interest

There are no conflicts of interest.

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