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Investigation of the relationship between "Sella Turcica Bridge" and "*Ponticulus Posticus*": A Lateral Cephalometric Study

Investigación sobre la Relación entre "Puente Silla Turca" y "*Ponticulus Posticus*": Un Estudio Cefalométrico lateral

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SUMMARY: The *ponticulus posticus* (PP) is a bridge of bone sometimes found on the atlas vertebra surrounding the vertebral artery and the first cervical nerve root. Sella turcica bridging (STB) is the fusion of anterior and posterior clinoid processes. The objective of this study was to find out the association between STB and PP. For the study, 752 digital lateral cephalograms were retrieved from the archived records of Necmettin Erbakan University, Faculty of Dentistry, Konya, Turkey. There was a significant relationship between the presence of STB and PP ($p=0.000$, $p<0.001$). This study indicates that there is a significant correlation between the presence of STB and PP.

KEY WORDS: Sella turcica; Lateral cephalometrics; Sella turcica bridging; Ponticulus posticus.

INTRODUCTION

The atlas is the first cervical vertebra of the spine. This cervical vertebra has several morphologic features that differentiate it from other vertebrae. *Ponticulus Posticus* (PP) is a variation occuring on the atlas vertebra (Bayrakdar *et al*., 2014). The PP means "little posterior bridge" in latin (Geist *et al*.; 2014; Sharma *et al*., 2010; Chitroda *et al*., 2013; Saokar & Nawale, 2014; Cho, 2009; Mudit *et al*., 2014). PP manifests as a partial or complete bony arch/bridge in the atlas vertebra (Pérez *et al*., 2014). In the literature, there are many terms that describe this anomaly (Table I), however, its most accepted name is PP (Baba *et al*., 2015).

Complete ossification of atlanto-occipital membrane leads to arcuate foramen, which may cause external pressure on the vertebral artery, especially during extreme rotatory movements of the head (Unur *et al*., 2004). The potential clinical significance of PP is controversial because the majority of patients with this finding are asymptomatic (Mudit *et al*., Chitroda *et al*.) but this bony arch may be linked to different symptoms, ranging from neckache to headache and migraine and it may also be incorrectly assessed during orthopedic surgery for fixation of atlas-axis, with consequent risk of damaging the vertebral artery (Chitroda *et al*.). It is important for the anatomist, radiologist, neurophysicians and neurosurgeons who are dealing with this region. Most prevalence studies had been performed by plain radiographs or dried atlas specimens (Cho). Because of the anomaly can be seen complete or incomplete there is a disagreement about the frequency of complete and incomplete cases (Geist *et al*.). The prevalence of this anomaly in the literature varies widely, with reports ranging from 4.3 % (Sharma *et al*.) – 68 % (Baba *et al*.).

The centre of sella turcica is routinely used as a cephalometric landmark to act as a reference point, S, for evaluating spatial position of both jaws as they relate to the cranial base. Anatomically sella turcica is a saddle-shaped depression in sphenoid bone which contains the pituitary gland (Shah *et al*., 2014). It consists four clinoid processes (two anterior and two posterior), the anterior border represented by tuberculum sellae and the posterior border by the dorsum sellae (Kucia *et al*., 2014). On a lateral cephalometric radiograph the image of sella turcica is U shaped (Shah *et al*.), it may be concave, flat or even convex (Kucia *et al*.). A deviation from normal size and shape of sella turcica can be an indication of a pathological condition of the gland (Shah *et al*.). Investigations concerning the sella turcica have not only focused on size but also on morphology. A normal morphological variation of sella turcica must be considered as it may vary greatly from indi-

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vidual to individual (Shah *et al*.; Nagaraj *et al*., 2015). The most frequent abnormality described in the orthodontic literature is sella turcica bridge (STB) (Kucia *et al*.). The fusion of anterior and posterior clinoid processes or a calcification of interclinoid ligament termed as STB (Shah *et al*., Kucia *et al*.). This osseous structure has been termed differently in the literature (Table II). The prevalence of STB or calcification of the interclinoid ligaments was reported in the literature between 1.1 % (Alkofide, 2007) – 18.6 % (Becktor *et al*., 2000).

Recently some studies have been done to establish connection of craniofacial skeletal anomalies with dental anomalies. It appears that tooth formation and tooth eruption and sella turcica bridging, as well as neck and shoulder skeletal development, are influenced by neural crest cells (Saokar & Nawale). Our purpose in this study is to find out association between STB and PP.

Table I. Various names used to describe the ponticulus posticus (PP).

NOMENCLATURE VARIATION FOR PP
Arcuate foramen
Atlas bridging
Canalis arteriae vertebralis
Foramen arcuale
Foramen atlantoideum
Foramen retroarticular
Foramen sagittale
Kimmerle anomaly
Kimmerle deformity
Kimmerle variant
Pons posticus
Posterior atlantoid foramen
Posterior glenoid process
Posterior glenoid spiculum
Posterior ponticulus
Retroarticular ring
Retrocondylar bony foramen

Table II. Various names used to describe the sella turcica bridge.

Nomenclature Variation for STB
interclinoid taenia
interclinoid bars
interclinoid osseous bridge
sella turcica bridge/bridging
sella bridge
roofing / bulging / calcification of the diaphragma sellae
calcified / ossified interclinoid ligament

MATERIAL AND METHOD

After local institutional research ethics committee approval (no.#2016.003), radiographs were retrieved from the archived records of Necmettin Erbakan University Faculty of Dentistry, Konya, Turkey. Orthodontic records, digital panoramic radiographs and digital lateral cephalograms from 752 patients, comprising 376 males and 376 females, within two age subgroups (9-15 and 16-24) were examined. The average age was 14.9-year-old (range 9-24 years). The distribution of the sample by age was presented in Table III.

Table III. Age distribution of the patient sample.

Age class (y)	N	Percent (%)
9-15	452	60.1
16-24	300	39.9
Total	752	100.0

Digital lateral cephalometric radiographs were obtained in standart position by using J MORITA (2D Veraviewpocs, MFG corp, Kyoto, Japan) machine with a tube voltage of 65 kV, tube current of 10 mA and exposure time of 4.9 s. The images were analyzed in a Dell Precision T7600 workstation (Dell, Round Rock, TX) using a 32-in Dell LCD screen with a resolution of 1280x1024 pixels in JPEG (Joint Photographic Experts Group) format.

Inclusion criteria

1. Healthy patients without any history of systemic diseases and long term use of drugs.
2. Patients in the age group of 9-24 years.
3. Patients advised for lateral cephalometric radiographs for orthodontic treatment.
4. High-quality radiographs which were taken by trained radiographic technicians in a standardized manner.

Exclusion criteria

1. Individuals with congenital defects in the craniofacial region like clefts and malformations
2. History of cranifacial fractures
3. Patients suffering from disorders of bone, nutritional deficiencies and endocrinal disturbances.

Each radiograph was carefully inspected for the presence of a STB and a PP, whether it was complete or partial (Fig. 1). Because we inspected neutral lateral radiograph only, we were not able to determine if the anomaly was uni or bilateral (Pérez *et al*., 2014). Direct visual method of examination under adequate illumination was used.

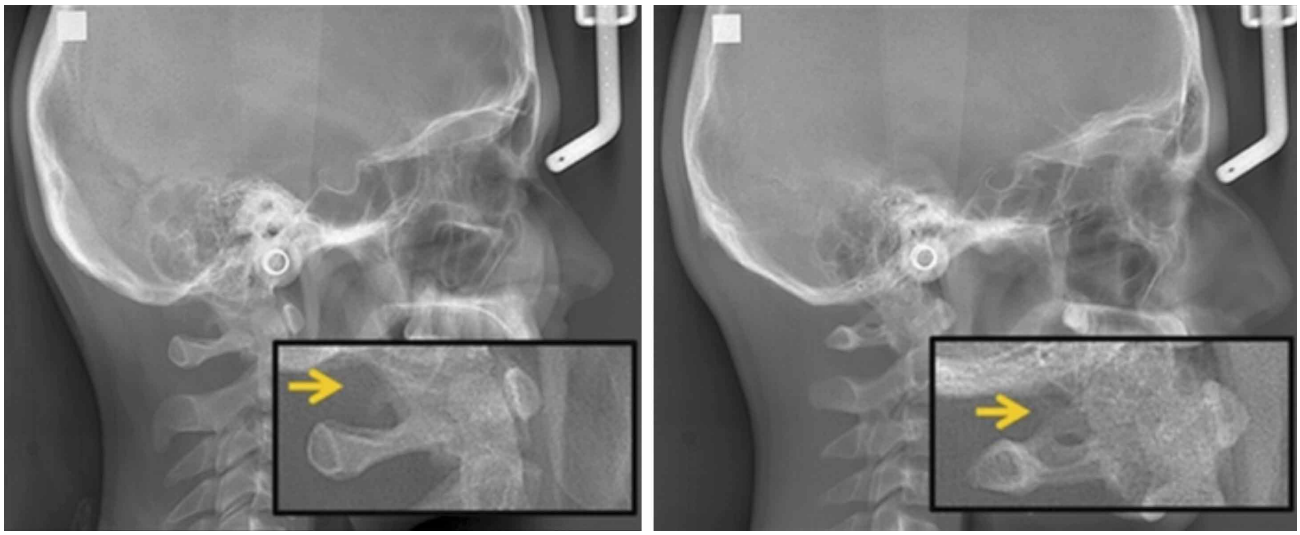

Fig. 1. Incomplete and complete form of PP.

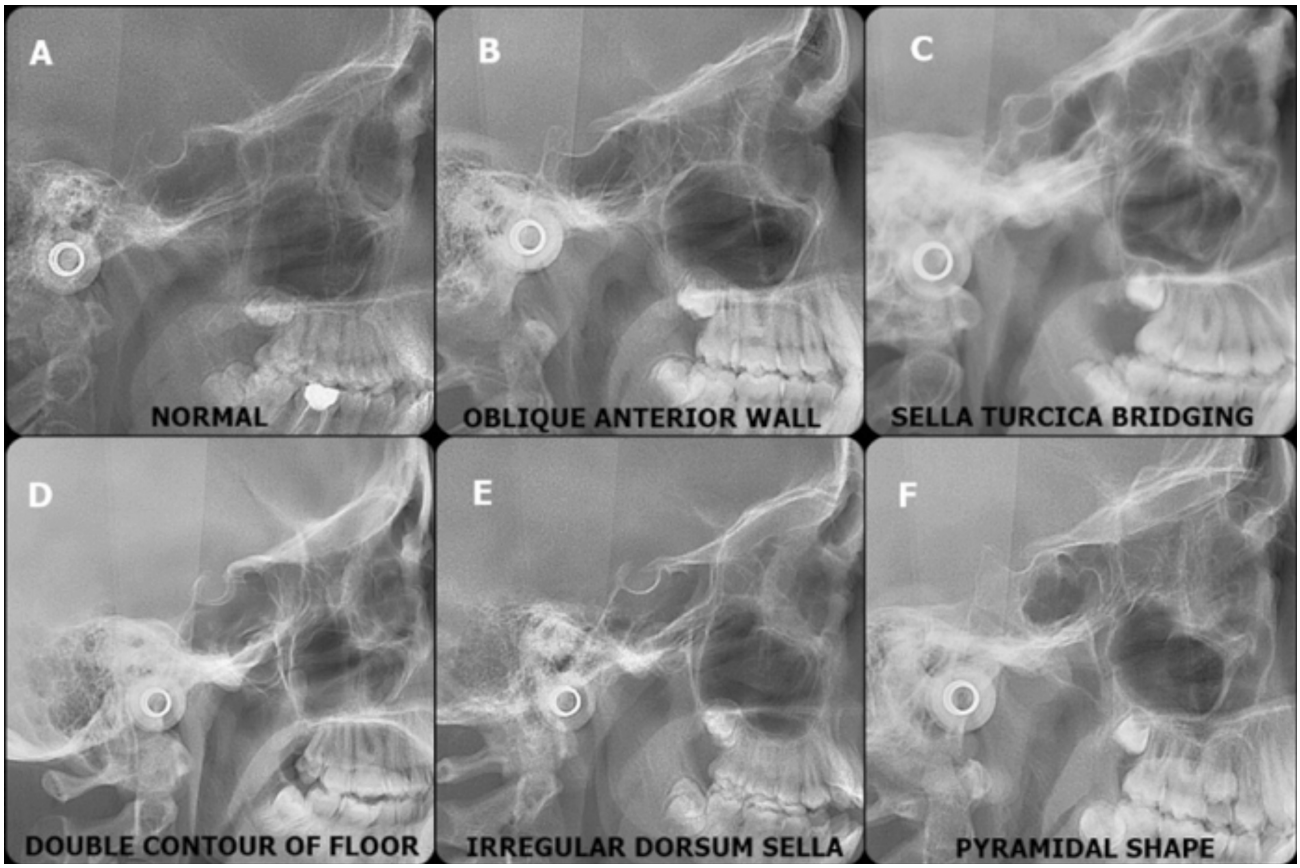

Fig. 2. Different morphological types of sella turcica according to Axelson *et al*: (a) normal sella turcica, (b) oblique anterior wall, (c) sella turcica bridge, (d) double contour of floor, (e) irregular dorsum sellae, (f) pyramidal shape.

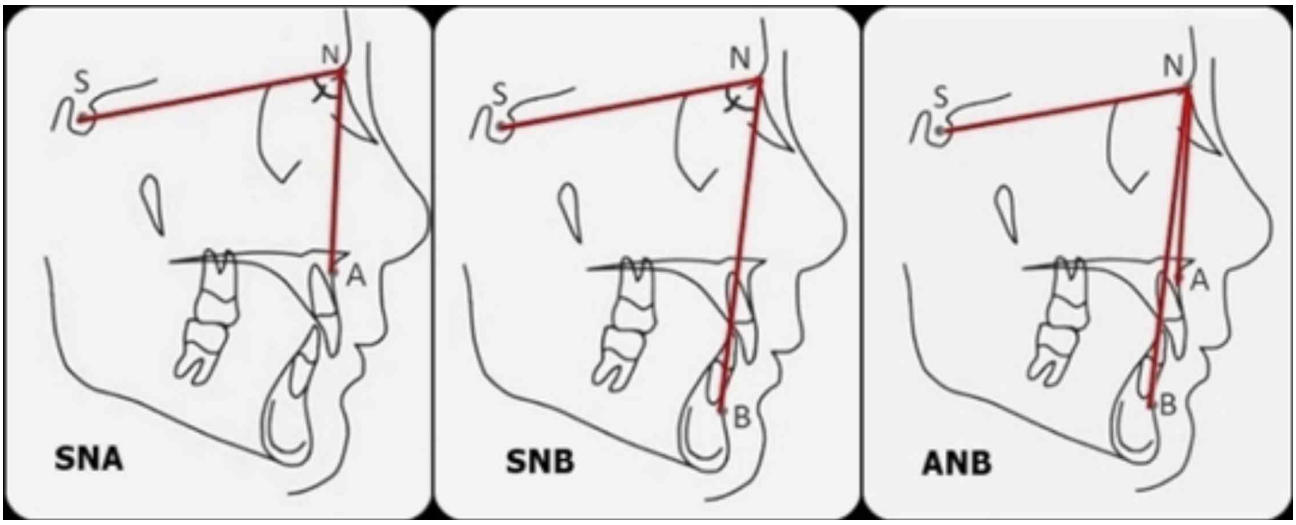

Fig. 3. Scheme used to determine the skeletal classes as for cephalometric measurements: Steiner's ANB angle on standart lateral cephalometric radiograph. OP= occlusal plane, N= nasion, A= subspinale and B= supramentale.

During initial examination all lateral cephalograms were observed by a radiologist and an orthodontist (MT and HK). To eliminate any error 100 randomly selected lateral cephalograms were re-examined separately by the same two authors 1 month after initial examination. There was almost perfect agreement between the two authors and the two examinations.

Shape and morphological appearance of sella turcica were assessed according to the method described by Axelsson *et al*. (2004) (Fig. 2). Orthodontic classification was carried out using Steiner analysis. Based upon the ANB angle, subjects were classified into Class I, II and III. ANB angle of ±2 belongs to Class I skeletal base. ANB angle>4 belongs to Class II skeletal base and ANB angle<0 belongs to Class III skeletal base (Fig. 3).

A chi-square test was used to find out the association of STB and PP. All statistical analyses were performed using SPSS 21.0 (Statistical package for social science Inc. Chicago, USA).

Table IV. Distribution of sella turcica type.

Sella type	Frequency	Percentage (%)
Normal sella turcica	231	30.7
Oblique anterior wall	62	8.2
Sella turcica bridge	182	24.2
Double contour of floor	22	2.9
Irregular dorsum sellae	122	16.2
Pyramidal shape	133	17.7
Total	752	100.0

Table V. Subjects grouped according to skeletal class.

Skeletal class	Frequency	Percentage (%)
I	231	30.7
II	411	54.7
III	110	14.6
Total	752	100.0

Table VI. PP distribution among patients.

PP	N	Percentage (%)
Normal	562	74.7
Incomplete	111	14.8
Complete	79	10.5
Total	752	100.0

RESULTS AND DISCUSSION

The morphology of sella turcica appeared to be normal in shape 30.7 % of subjects, regardless of sex, age, or skeletal type (Table IV). Table V shows the distribution of skeletal classes of patients. The majority of subjects were in class II. There was no statistically significant difference between skeletal classes and sella turcica bridging ($p>0.05$).

The prevalence of incomplete and complete calcification of PP were given in Table VI. No statistically significant association were observed between skeletal classes and PP ($p>0.05$).

Table VII. Association between sex and PP, sex and sella bridging (*significant).

Age (y)	Prevalence	
	Sella Bridging	PP
9-15	20 %	23 %
16-24	30 %	28 %
p value	0.001*	0.307

Table VIII. Associaton between sex and PP, sex and sella bridging.

Sex	Prevalence	
	Sella Bridging	PP
Female	23 %	21 %
Male	24 %	28 %
p value	0.466	0.076

STB and PP prevalence were increased by aging (Table VII). Although there was statistically significant association between age and sella bridging, there was no statistically difference between age and PP. No statistically significant association were observed between sex and PP, sex and sella bridging.

Although males had higher values of prevalence, no statistically significant association were observed between sex and PP, sex and sella bridging (Table VIII).

The prevalence of incomplete, complete PP and STB was 14.8 %, 10.5 % and 24.2 %, respectively. There was statistically significant association between STB and PP ($p<0.001$). PP was found to be present more in the subjects with sella bridging compared to subjects without bridging (Table IX).

Table IX. Association between STB and PP (*significant).

Patients	PP		Total	p-value
	Present (N)	Absent (N)		
With sella bridging	78	104	182	0.000*
Without sella bridging	112	458	570	
Total	190	562	752	

Table X. Association between PDC and sella bridging, PDC and PP (*significant)

Patients	Prevalence	
	Sella bridging (%)	PP (%)
With PDC	26	29
Without PDC	25	25
p value	0.171	0.040*

The prevalence of PP was increased in patients with palatally displaced canines (PDC) ($p<0.05$) but there was no statistically significant differences were observed between sella bridging and PDC ($p>0.05$) (Table X).

DISCUSSION

The lateral cephalograph is the most common diagnostic radiograph used in clinical orthodontics (Mudit *et al.*, Sharma *et al.*). They are used to evaluate the craniofacial and dental structures, but they also include other diagnostics information about the skull, face and upper cervical spine, and various occult pathologies and rare normal variants involving the head or spine (Pérez *et al.*, 2013). Identifying the affected side of atlas is very difficult with lateral radiographic views because the presentation of PP can be uni or bilateral. The exact characterization is possible only by three dimensional (3D) computed tomography (CT) reconstruction (Pérez *et al.*, 2014). Additionaly cone beam CT (CBCT) has great advantages over planar skull radiography in visualizing the cervical vertebrae. CBCT provides demonstration of the vertebral column in three planes of space, thereby providing the benefits of conventional CT with generally lower radiation exposure and greater spatial resolution (Geist *et al.*). Plain film radiographs are useful to indicate the presence of PP; but the detection of the osseous bridges on plain film radiographs depends on the thickness of the bridge, a fine thread of ossification may be difficult to detect and thinner bridges are detected using 3D CT scanning only (Pérez *et al.*, 2014). Cho, compared 3D CT scans against plain film radiography and found statistically significant differences in the frequencies of the two types of radiographic studies influenced by the different diagnostic values of CT scans contrasted with the plain film radiography.

Autopsy studies have reported lower rates of STB compared with the higher rates found in radiographic studies. The differences between direct anatomical studies and data from lateral cephalometric radiographs have been attributed to superimposition of the overlapping clinoid processes of the sella turcica (Abdel-Kader, 2007). For this reason, only three dimensional imaging such as CT or CBCT could give more precise information about the sella area. However, routine use of these imaging techniques in patients is not advised due to the higher exposure to radiation, particularly with CT.

Table XI. The prevalence of PP as reported in the literature.

Authors	Year	Sample size	Review source	Prevalence (%)
Unur *et al.*	2004	351	Lateral spine radiographs	5.1
Sharma *et al.*	2009	228	Lateral cephalographs	4.3
Chitroda *et al.*	2013	500	Lateral cephalographs	60
Bayrakdar *et al.*	2014	730	CBCT	17.4
Pérez *et al.*	2014	1056	Lateral cephalographs	19.79
Geist *et al.*	2014	576	CBCT	26.2
Baba *et al.*	2015	1000	Lateral cephalographs	68
Present study	2016	752	Lateral cephalographs	25.3

Table XII. The prevalence of sella bridging in the literature

Author	Year	Sample Size-Source	Prevalence (%)
Becktor *et al.*	2000	177-Lateral cephalometrics	18.6
Erturk *et al.*	2004	119-Dry skull	8.18
Alkofide.	2007	180-Lateral cephalometrics	1.1
Kolagi *et al.*	2011	112-Dry skull	8.04
Pérez *et al.*	2013	417-Lateral cephalometrics	4.31
Nagaraj *et al.*	2015	200-Lateral cephalometrics	7.5
Present study	2016	752-Lateral cephalometrics	24.2

In this investigation, the overall prevalence of complete and incomplete PP was 25.3 %, similar to the results of some researchers (Geist *et al*.; Pérez *et al*.; 2014). Other authors, however, have reported a smaller percentage of PP (Unur *et al*.; Sharma *et al*.). The prevalence of PP has been reported to be between 4.3 % (Sharma *et al*.) and 68 % (Baba *et al*.). Researchs in the literature represent many different ethnic and racial groups, which may explain the wide range of prevalence (Geist *et al*.). Mudit *et al*., suggested that ethnicity could change the prevalence of this entity. Standardization and disagreement between observers are anohter problems, making comparisons between reports difficult (Geist *et al*.). There are also many factors determining the visibility of PP in radiographic images such as film processing and proper selection of kVp and mAs.

We found increasing percentages of PP from the youngest to the oldest age group in accordance with Geist *et al*. This suggests that PP bridges may form more frequently after puberty (Geist *et al*.). Various theories have been put forward by different researchers for the origin of the bridges leading to the foramen formation. The mechanism of formation is not clearly understood and a subject of much debate but a number of theories have been put forward including (Tubbs *et al*., 2007): a genetic trait, a remnant manifestation of an occipital vertebra, the result of external mechanical factors such as carrying heavy objects on the head, an ossification related with increasing age, and the activation of a special osteogenic potency existent in the craniocervical junction region in the connective tissue surrounding the vertebral artery possibly induced by the pulsation of the vertebral artery.

This study found a higher percentage of males with PP but there is no consensus regarding the prevalence of PP in males compared with females (Geist *et al*.). The frequency of PP increased in subjects with palatally displaced canines in accordance with Leonardi *et al*. (2009). It may act as a useful diagnostic predictor of susceptibility to local dental problems.

The prevalence of STB shows great variation among different populations between 1.1 % (Alkofide)-18.6 % (Becktor *et al*.). According to our results STB (24.2 %) are not so infrequent radiographic findings in Turkish orthodontic patients. The prevalence of STB was higher in the older age group in the present study but it also could be seen in the younger age group. Formation of the STB may result directly from the pattern of sphenoid development or can be dictated by the physiological activities of chemical compounds that are involved in embryogenesis and build up of the bones (Skrzat *et al*., 2006).

There was a clear tendency towards a greater frequency of a STB in patients with severe craniofacial deviations (Becktor *et al*.). The morphological variations of sella turcica with greater severity are more commonly seen in syndromic patients such as Down's syndrome, William's syndrome and Seckel syndrome (Nagaraj *et al*.). The occurence of STB has been described as a radiographic feature in basal cell carcinoma (Gorlin-Goltz) syndrome, Rieger syndrome, Axenfeld-Rieger syndrome and other disorders and syndromes. Sellar bridges were demonstrated radiographically to a 25 % extent in idiots, to 20 % in

criminals, to 15 % in epileptics, and to 38 % in other cases with mental disorders (Kolagi *et al*., 2011).

The interclinoid ligament bisects the wall of the cavernous sinus, dividing it into two triangles; carotid trigone anteromedially and occulomotor trigone posterolaterally. Thus ossification of this ligament may influence such structures as the internal carotid artery or the occulomotor nerve. Anomalies of sellar region may create difficulty in the regional surgery planning. Removing the anterior clinoid process is an important step in exposing the structures in the cavernous sinus and is highly complicated due to the neuronal and vascular realtionships. The presence of ossified interclinoid ligament makes the removal of anterior clinoid process more difficult and increases the risks especially in the presence of aneurysm (Kolagi *et al*.).

Our results indicated that there was a statistically significant association between STB and PP. This relationship may be based on the involvement of neural crest cells and/or homeobox or hox genes during the developmental stage (Saokar & Nawale). Our results in contrast with Leonardi *et al*. They did not found any relationship between STB and PP, but we are in accordance with the study done by MacRae (1953) and Saokar & Nawale. Mac Rae found out the different variants of atlas could be accompanied by other defects within the vertebral column, such as deformation of the skull base, particularly within the Turkish saddle, extended styloid process or cervical ribs. Saokar & Nawale observed that the incidence of PP was to be more in the group with sella bridging as compared to the group without bridging.

It appears that tooth formation and their eruption and sella turcica bridge calcification, as well as neck and shoulder skeletal development, are all influenced by neural crest cells. Because the teeth, the head, and the cervical spine are influenced in their development by neural crest cells, it is reasonable to assume that any disturbance of neural crest cells might interfere with the development of one or more systems that are under their influence (Leonardi *et al*.)

Sekerci *et al*. (2015) suggested that there was a significant relationship between the presence of PP and elongated styloid process. According to our study there was a significant association between STB and PP. Based on these results future researchs into the molecular basis of craniofacial and skeletal abnormalities could benefit from the reporting of new clinical interrelationships such as those presented here (Leonardi *et al*.).

In conclusion this study suggests that there is a significant correlation between the presence of PP and STB. Bearing this in mind, our findings should widen the idea somewhat that PP is seen only in conjunction with STB or other skull and skeletal anomalies. If PP and STB are associated with other clinically and radiologically discernible features that often occur together and could be regard as part of a syndrome.

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RESUMEN: El *Ponticulus Posticus* (PP) es un puente de hueso que se encuentra, a veces, en el atlas y rodea la arteria vertebral y la primera raíz del nervio cervical. El puente de la silla turca (PST) es la fusión de los procesos clinoides anteriores y posteriores. El objetivo de este estudio fue conocer la asociación entre PST y PP. Para el estudio, fueron utilizados 752 cefalogramas digitales laterales, obtenidos de los registros archivados de la Facultad de Odontología de la Universidad Necmettin Erbakan, Konya, Turquía. Hubo una relación significativa entre la presencia de PST y PP ($p = 0,000$, $p < 0,001$). Este estudio indica que existe una correlación significativa entre la presencia de PST y PP.

PALABRAS CLAVE: Silla turca; Cefalometría lateral; Puente silla turca; ***Ponticulus Posticus*****.**

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