Ponticulus posticus: is it important for a dentist as a radiological finding?

Ponticulus Posticus: Radyolojik bir bulgu olarak bir diş hekimi için önemli midir?

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SUMMARY

Developmental anomalies of the atlas are of interest not only to anatomists but also clinicans, radiologists, surgeons, who should be aware of their distinct morphological manifestations as well as correlated clinical expressions. Dentists should look carefully for Ponticulus posticus (PP) because these abnormalities may be related to otherwise unexplainable head and neck pain, visual disturbances, problems with speech and swallowing, vertigo, vascular problems and other symptoms related to compression of the vertebral artery and suboccipital nerve. The aim of this paper, although the dentists especially oral and maxillofacial radiologists and orthodontists are not directly concerned with the management of cervical spine anomalies to sensitize them to realize the cervical spine and be equipped to identify differences from normal anatomy.

Key words: Ponticulus posticus, lateral cephalogram, foramen arcuale, dentistry.

ÖZET

Atlas omurundaki gelişimsel anomaliler sadece anatomistlerin değil, morfolojideki farklılığın kliniğe yansımasının bilincinde olması gereken klinisyenlerin, radyologların ve cerrahların da ilgi alanıdır. Diş hekimleri, nedeni açıklanamayan baş ve boyun ağrısı, görme rahatsızlıkları, konuşma ve yutma problemleri, vertigo, vasküler problemler, vertebral arter ve suboksipital sinirin sıkışması ile ilgili semptomlarla ilişkili olabileceğinden, bu durumların varlığında Ponticulus posticus'u (PP) dikkatlice incelemelidirler. Bu yazının amacı, diş hekimlerini, özellikle oral ve maksillofasiyal radyologları ve ortodontistleri, doğrudan servikal omur anomalilerinin tedavileri ile ilgili olmasalar da, servikal omurları inceleme ve normal anatomiden ayrılan farklılıklarını saptama konusunda duyarlı hale getirmektir.

Anahtar kelimeler: Ponticulus posticus, lateral sefalogram, foramen arcuale, diş hekimliği.

INTRODUCTION

Craniocervical junction is the area comprising the inferior portion of the occipital bone that surrounds the foramen magnum and the first two cervical vertebrae, atlas and axis. Due to its complicated embryonic development, this area is easily susceptible to skeletal and neural developmental variants and anomalies, producing a wide spectrum of symptom.[1]

The first cervical vertebra, the atlas, is the most variable human vertebra.[2] The ponticulus posticus (PP), foramen arcuale or "Kimmerle's anomaly" is a poorly understood anomaly of the atlas vertebrae.[3,4] The PP, which seems to be the consequence of the complete or incomplete ossification of the posterior atlantooccipital membrane over the vertebral artery groove, has become a significant abnor-

mality of the atlas in the management of atlantoaxial instability, which has gained popularity. Therefore, developmental anomalies of the atlas are of interest not only to anatomists but also to clinicians, radiologists, surgeons, and chiropractors, who should be aware of their distinct morphological manifestations as well as correlated clinical expressions.[5,6]

Table 1: Various names used to describe the ponticulus posticusble

NOMENCLATURE VARIATION FOR PPPosticus
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

In the literature, there are many terms that describe this anomaly (Table 1),
however, its most accepted name is PP.[3,4] Its origin, embryology, prevalence, clinical significance, and implications are all without definitive answers. Records of its descriptions have been found dating back to the 1800's. It has been included in the differential diagnosis of numerous diseases and considered an indication as well as a contraindication for several surgical procedures.[7]

Anatomy

The PP means "little posterior bridge" in Latin[3,6,8-18] which describes an anomalous malformed bony bridge between the posterior portion of the superior articular process and the posterolateral portion of the superior margin of the posterior arch of the atlas.[9] The normal atlas (Figure 1) is a ring-like structure consisting of two lateral masses connected by a short anterior arch and a longer posterior arch. It is the widest cervical vertebra, with its anterior arch approximately half as long as the posterior arch. The posterior arch corresponds to the laminae of other vertebrae. On its upper surface is a wide groove for the vertebral artery and the first cervical nerve. The posterior atlantooccipital membrane when ossified partly or wholly forms a bony arch over the vertebral groove, called arcuate foramen, which contains important anatomic structures such as vertebral artery and the suboccipital nerve.[19] This bony arch is known as the PP[17] and is often bilateral[20] and can be divided into two types: partial (incomplete) and complete (Figure 2 and 3).[10,21] It was first reported by MacAlister[22] in 1893.

Figure 1. Normal atlas

Figure 2. Incomplete PP

Figure 3. Complete PP and foramen arcuale

Young et al.[14] reported that putting a screw into PP during C1 lateral mass screw placement could cause injury to the vertebral artery. Although PP is usually regarded as a simple anatomic variant on the atlas vertebrae, it is an important, common anomaly of the posterolateral aspect of the posterior arch of the atlas.[16]

Formation Mechanism

The PP is formed by the bony spurs arising from the posterior surface of the lateral mass to the posterior arch of the atlas, and histologically is composed by a cortex and cancellous bone matrix with easily distinguishable circular lamellar patterns, all signs of endochondral ossification; those findings suggests that the PP derives from the embryonic tissue of the dorsal arch of the pro-atlas, and moreover, cartilagi-

nous posterior bridges have been seen in fetuses and children.[10]

PP has been documented in children as young as two years old and thus some authors[23,24] have commented that this structure is simply a regressive and disappearing morphological phenomenon. According to Schilling et al.[3] presence of the PP is a condition independent of age, and therefore should not be considered a calcification or an ossification of the lateral segment of the posterior atlantooccipital ligament, but rather an ossification with functional significance, developed in other primates[19] in order to protect the passage of the vertebral artery in a region which, by its sinuosity, is susceptible to being damaged or compressed as a result of craniocervical dynamics (Figure 4).[3] On the other hand, PP has been described in classical literature as an anatomical variation that originates in the ossification of the lateral segment of the posterior atlantooccipital ligament or the capsule of this joint.[3]

Figure 4. Schema of lateral views of the first and second cervical vertebrae, demonstrating an arcuate foramen of the atlas (top) and revealing the course of the vertebral artery (dark black) within the arcuate foramen formed by the ponticulus posticus (bottom).

The mechanism of formation is not clearly understood and a subject of much debate[25] but a number of theories have been put forward including: a genetic trait;[25-29] an occipital vertebra;[25,28] the result of external mechanical factors such as carrying heavy objects on the head;[25,28] an ossification related with increasing age;[15,25,30-32] ethnicity[17,33] 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.[15,28,29]

Clinical Significance

During the past 50 years, a greater awareness has developed of how minor anomalies of the atlanto-occipital region may result in pathophysiologic conditions of clinical significance.[34] The potential clinical significance of PP is controversial because the majority of patients with this finding are asymptomatic[11,15,17] 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 C1-C2, with consequent risk of damaging the vertebral artery.[35] Spine surgeons, neurosurgeons, otorhinolaryngologists, neurologists, and chiropractors interest in this anomaly. It has been included in the differential diagnosis of numerous diseases and considered an indication as well as a contraindication for several surgical procedures.[25]

The ossification of ligamentous structures in various parts of the body may result in clinical problems and complications in regional surgery.[19] Ercegovac and Davidovic[36] alleviated the symptoms of vertebrobasilar insufficiency by surgical removal of the bony ring in 8 cases. Recent case studies of ultrasonographic analysis lend further support to the suggestion that the PP compresses the vertebral artery because its removal appears to allow "normal" circulation and the reduction of symptoms.[37]

Lamberty and Zivanovic[23] state that "the symptoms of vertebrobasilar insufficiency may be caused by the bony rings around the vertebral artery in the absence of identifiable arterial disease and that it may be a predisposing factor when arterial disease is present". They identified the PP as the causative factor in headaches, vertigo, eye pain, and photophobia. The mechanism is unclear, although it is thought by some to be due to compression of the vertebral artery by the PP, leading to ischemia of the vertebrobasilar circulation.[20]

In the literature, PP has been reported to be associated vertebrobasilar insufficiency, cervical pain syndrome, migraine without aura, onset of acute hearing loss[16] and it is one of the causes of posterior circulation ischemia, cervicogenic headache and clinical complaints such as vertigo, neck pain of discopathy. PP is also associated with Barré-Lieou syndrome which manifests with symptoms of headache, retroorbital pain, vasomo-

tor disturbance of the face and recurrent disturbances of vision, swallowing and phonation due to alteration of blood flow within the vertebra. In patients with this syndrome the foramen was fractured and a periarterial sympathectomy was performed with good results.[15] In addition, PP is attached to the antlanto-occipital membrane, which is connected to the dura. Especially when the head is moving, the neurodynamic process may lead to conditions cited above because of traction on the dura, and this can result in pain.[9,16] Wight et al.[20] found increased presence of PP of the atlas in migraine sufferers.

The presence of the PP has been related with shoulder and arm pain, neck pain, headaches, and dizziness.[38] Headache, neck and shoulder / arm pain as well as vertigo have been found with significantly greater frequency in patients with complete PP compared with partial PP.[6]

Leonardi *et al.*[39] carried out an investigation to determine the prevalence of atlanto-occipital ligament calcification on lateral X-rays of Nevoid Basal Cell Carcinoma Syndrome patients, aiming to assess the effectiveness of this sign in diagnosis of the syndrome. The syndromic patients showed an increased prevalence of atlantooccipital ligament calcification than was found in the general population.

In terms of surgery, PP has become an important anomaly of the atlas since the lateral mass screws began being used for the treatment of atlantoaxial instability.[9,40] Atlantoaxial instability is excessive movement at the junction between the atlas and axis. This problem may lead to such symptoms as balance problems, blurred vision, frequent head and neck pain, difficulty swallowing, dizziness, fullness in the ears, migraine headache, neck pain with no motion, reduced activity, severe fatigue, suboccipital headache, tinnitus and vertigo. A lateral mass screw for the fixation of the atlas is a popular treatment for managing atlantoaxial instability. PP is a significant anomaly of the atlas which this procedure applied. The procedure is a difficult one because the region includes the epidural venous plexus and the major occipital nerve. Injury to the region can cause significant bleeding and occipital neuralgia,[11,16,18] stroke or even death by thrombosis, embolism, or arterial dissection.[11] A preoperative lateral radiograph of neck should be done in patients before lateral mass screw fixation. This will help in proper identification of this anomaly and prevent the injury to the vertebral artery.[15] PP is suspected or observed on the radiographs of a patient CT scans will be helpful planning for placement of these screws as well.[18]

Epidemiology

The anatomical anomaly, PP, is not rare, occurring in nearly 17% of patients in radiographic and cadaveric studies.[41] Elliott and Tanweer41 carried out a systematic review and analyzed radiographic, cadaveric, and surgical data and reported the prevalence of PP. In 44 reports describing the presence of PP in online databases, 21.789 cases (15.542 patients and 6247 bony / cadaver specimens) were included in this series. The overall prevalence of PP was 16.7%, 16.6% on radiographic studies, 17.2% on CT study, and 18.8% in cadaver specimens.

The prevalence of this variant has been reported differently by different authors.[42] A comparison of the prevalence of PP observed by different authors has been presented in Table 2.

Table 2: Published cadaver / radiological studies on the prevalence of PP.

Authors, year	Review Source	Sample Size	Population	PP (%)
Selby *et al.*[26] 1955	Lateral radiography	306	North America	27.12
Romanus and Tovi[43] 1964	Cadaver	105	Sweden	14.29
Lamberty and Zivanovic[23] 1973	Cadaver	60	England	36.67
Saunders and Popovich [27] 1978	Lateral radiography	592	Canada	29.22
Farman *et al.*[44] 1979	Lateral radiography	220	South Africa	26.82
Taitz and Nathan[32] 1986	Cadaver	672	Various continents	33.78
Stubbs[45] 1992	Lateral radiography	1000	North America	18.70
Mitchell[33] 1998	Cadaver	1354	South Africa	10.19
Hasan *et al.*[46] 2001	Cadaver	350	Northern India	6.57
Manjunath[29] 2001	Cadaver	60	Southern India	11.70
Wysocki *et al.*[2] 2003	Cadaver	95	Poland	31.58
Kavakli *et al.*[1] 2004	Cadaver	86	Turkey	22.09
Le Minor and Trost[47] 2004	Cadaver	500	France	14.20
Cakmak *et al.*[38] 2005	Lateral radiography	416	Turkey	13.46
Young *et al.*[14] 2005	Lateral radiography	464	North America	15.52
Paraskevas *et al.*[28] 2005	Cadaver	176	Northern Greece	34.66
Lee *et al.*[48] 2006	Cadaver	709	North America	26.94
Krishnamurthy *et al.*[19] 2007	Cadaver	1044	India	13.79
Tubbs *et al.*[25] 2007	Cadaver	60	North America	5.00
Gupta[49] 2008	Cadaver	55	India	10.91
Kobayashi *et al.*[50] 2008	Cadaver	50	Japan	10.00
Simsek *et al.*[51] 2008	Cadaver	158	Turkey	9.49
Cho[13] 2009	CT	200	Korean patients with cervical symptoms	15.50
Karau *et al.*[52] 2010	Cadaver	102	Kenya	52.94
Chitroda *et al.*[11] 2013	Digital lateral cephalography	500	Gulbarga population	68.40
Geist *et al.*[8] 2014	CBCT	576	American Orthodontic patients	26.2
Bayrakdar *et al.*[16] 2014	CBCT	730	Turkish population	17.40
Sekerci *et al.*[6] 2015	CBCT	698	Turkish population	36,8

Mudit *et al.*[17] suggested that ethnicity could change the prevalence of this entity. Aside from the characteristics of the population, the difference between the various studies may be related to the radiographic factors such as use of grids, photographic characteristics of X-ray film, film processing (development) and proper selection of kVp and mAs. Both sharpness and resolution may lead to difficulty in detecting a fine thread of ossification in posterior atlantooccipital membrane ligament. However, the effect of these factors in the radiographic detection of PP needs to be proven by large-scale cadaver studies.[30]

On the other hand, Table 2 combines data from osteological analysis of cadaver specimens as well as radiographic series of patients. The populations studied in the radiographic studies varied. Many were orthodontic patients but some patients did have cervical complaints. Some studies reported a higher prevalence of this anomaly in patients with cervical complaints or with migraines and cervicogenic headaches.[41]

Although lateral radiographs may have lower sensitivity compared to CT or direct assessment of the bony specimen, there was not a large discrepancy in the prevalence of PP between the methods.[41]

Prevalence has been found to vary with race, gender and side.[42] Few authors have observed it more commonly among Whites than Blacks[33] and in males than females.[43] Numerous studies have reported a higher prevalence of cervical spine anomalies in cleft lip and palate patients.[9]

Imaging Modalities

The cephalogram is a useful screening tool for detection of this anomaly (Figure 5).[9] The lateral cephalogram is the most common diagnostic radiograph used in clinical orthodontics. The cervical spine area present in lateral cephalograms. Although the skeletal maturation evaluation using cervical vertebrae and its modified version, cervical vertebrae maturation index (CVMI), is now commonly used to interpret the growth potential of young patients, inadequate attention is paid to the radiological anatomy of this region with a view to identifying pathology. Significant cervical spine pathology can be detected on the routine lateral cephalogram.[9]

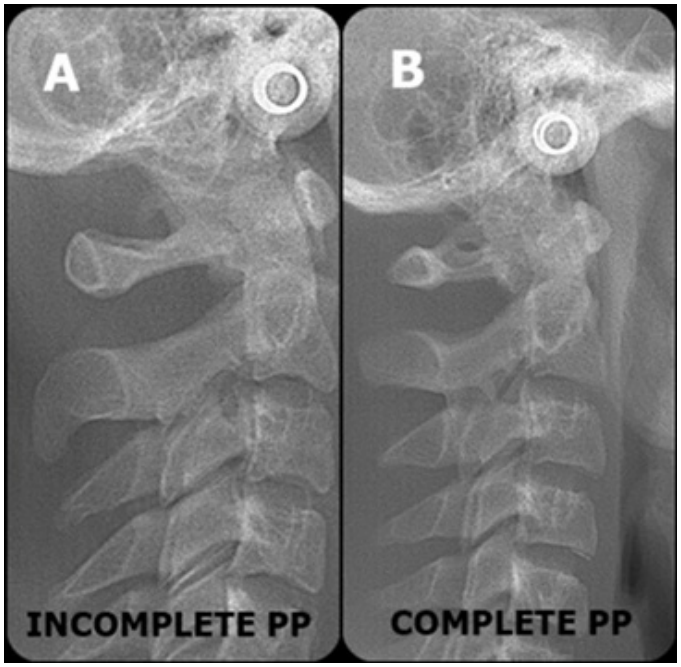

Figure 5. Cropped lateral cephalogram of complete and incomplete PP.

The presentation of the bony arches or bony bridges can be partial or complete, unilateral or bilateral, as mentioned before. Identifying the affected side of atlas is very difficult with lateral and anteroposterior radiographic views.[3,41] 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. Therefore, the true prevalence of the PP might only be determined using 3D CT scan because of its high diagnostic value, but it would expose patients to an high level of radiation.[10] Kim *et al.*[18] and Cho[13] 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.

Cone-beam computed tomography (CBCT), which can definitively measure the length of the anatomical structures of the craniofacial region, was introduced as a new and alternative modality. This recently designed technology has become an important tool for the diagnostic imaging of oral and maxillofacial osseous structures, providing professionals with access to excellent image quality and greater diagnostic accuracy and sensitivity.[5,6] CBCT has low doses of radiation, a short imaging time, and better image resolution compared with CT.[16]

CONCLUSIONS

In conclusion, the finding of PP can be of great impor-

tance for patients, in whom these anomalies assume clinical significance during management of cervical spine surgical intervention, especially those requiring screw placements in the lateral mass region of atlas. Apart from this surgical aspect, it may assume significance in certain cases of headache and migraine. Thus, care must be taken to account for it on lateral cephalograms of dental patients which is a baseline screening tool for detecting anomalies and pathology in the cervical spine region. If any such anomaly is detected or suspected by a dentist, it must be documented in the patient's health record and specialist consultation must be requested. A CT scan can be used to demonstrate the size and morphology of the PP, if required.

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