ORIGINAL ARTICLE

A survey of ponticulus posticus: Radiological analysis of atlas in an orthodontic population based on cone-beam computed tomography

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Abstract

Background: The ponticulus posticus (PP; Latin for little posterior bridge) has become an important anomaly of the atlas, as the use of the C1 lateral mass screw has become common in treating atlantoaxial instability.
Aim: The purpose of this study was to retrospectively determine the prevalence and morphologic characteristics of PP in an orthodontic patient population using cervical three-dimensional (3-D) cone beam computed tomography (CBCT) images.
Material and Methods: A retrospective study was conducted by selecting cervical 3-D CBCT images of 374 adolescent population and examining them for the presence and type of PP.
Results: 161 patients with 298 complete or partial or bilateral or unilateral PPs were identified based on the 374 cervical 3-D CBCT scans. The prevalence of posticulus ponticus was founded 43.04% in adolescent population.
Conclusion: Our results show that the presence of this anomaly should be carefully examined using preoperative lateral radiographs before lateral mass screw placement. If a PP is suspected or confirmed on radiographs, 3-D CBCT scanning should be considered before lateral mass screw placement into the posterior arch because of the variation in the size and shape of PPs and the possibility of injury.

Key words: Cone-beam computed tomography, lateral mass screw, ponticulus posticus

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Introduction

The atlas (C1) is the most superior (first) cervical vertebra of the spine. It has several morphologic features that differentiate it from other vertebrae, including the absence of a vertebral body, a unique ring-shaped arrangement surrounding the dens of the axis that is called the second cervical vertebra and that has a unique articulation with the cranium from the cephalic perspective. The normal atlas 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 being approximately half as long as the posterior arch.[1] The ponticulus posticus (PP) is a bony bridge arising from the posterior portion of the superior articular process atlas and the postero-lateral portion of the superior margin of the posterior arch of the atlas that completely or partially encircles the vertebral artery.[2,3]

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The PP was not of concern for spine surgeons until its surgical significance in the insertion of screws into the lateral mass of the atlas was recently reported.[4] There has been a steady increase in the number of patients treated with C1 lateral mass screws (C1LMSs) through the posterior arch. Although different kinds of skeletal maturation evaluations[5,6] based on cervical vertebrae are 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.[7] Knowledge of the PP anomaly is critical to surgeons performing posterior atlantoaxial fusions.[8] Since the treatment of atlantoaxial instability was revolutionized by the introduction of the C1LMS insertion,[9] many variations of the method have been described and successfully used.[10,11] Young *et al*.[12] reported that mistaking the PP for just a broad posterior arch of the atlas during C1LMS placement could cause injury to the vertebral artery.

The prevalence of PP has been reported to be between 5.14% and 37.83% in the Western population.[5,13,14] However, we could only find a few studies[15,16] on its prevalence or morphologic characteristics in an Asian population. It is very important to be aware of the posterior neural arch of C1 when performing lateral mass screw insertion to avoid vertebral artery injury. Paraskevas *et al*.[17] believe that the prevalence of PP is related to age; however, there are no studies evaluating the presence of this formation in adolescents.

The exact characterization of PP is possible only with three-dimensional technology, such as cone-beam computed tomography (CBCT). This relatively new and alternative modality can be used to measure the length of the anatomical structures of the craniofacial region. It has become an important tool for the diagnostic imaging of oral and maxillofacial osseous structures and has excellent image quality and greater diagnostic accuracy and sensitivity. Therefore, we investigated the prevalence and morphologic features of PP in Turkish patients reporting to our department for diagnosis who were all healthy and free of any systemic or musculoskeletal problems. The purpose of this study was to determine the frequency of the anomaly and to identify its anatomical features in relation to surgical approaches to the posterior aspect of the atlas among a group of adolescent patients using CBCT.

Materials and Methods

We designed a retrospective study consisting of the CBCT (Newton 5G, QR, Verona, Italy) images of patients who presented at the Oral and Maxillofacial Radiology Department at the Erciyes University, Kayseri, Turkey. All the patients had been referred for diagnosis and treatment planning, which included orthodontics.

CBCT scans were retrieved from the archives of the department and examined for cervical spine anomalies, particularly PP. Exclusion criteria included inadequate picture quality (artifacts caused by metallic implants or osteosynthesis plates; low resolution; and patient movement during imaging). Patients presenting with congenital anomalies, such as cleft lip and palate, were not included. In addition, patients with other syndromic conditions involving the craniofacial region were excluded. Three-dimensional CBCT digital images of 374 consecutive patients (148 males and 226 females) were examined.

The CBCT images were analyzed with the inbuilt software (NNT) on a dell precision T5400 workstation (Dell, Round Rock, TX, USA) with a 32-inch dell liquid crystal display screen with a resolution of 1280 × 1024 pixels. These images were reconstructed into three-dimensional images and carefully inspected for the presence of a PP and whether it was complete or partial. A complete PP was defined as a clear bony bridge between the superior articular process and the posterior arch of the atlas on three-dimensional CBCT images. A partial PP was defined as a distinct bony spicule extending from the superior articular facet overhanging the dorsal arch.

A direct visual method of examination under adequate illumination was used. The examination of the PP was performed by two experts (AES and SKB) in assessing CBCT volumetric data. To eliminate any errors, 75 randomly selected images were re-examined separately by the same two authors 1-month after the initial examination. There was complete agreement between the two authors and the two examinations. The prevalence according to gender was calculated.

Statistical analysis was conducted with a Chi-square test using SPSS version 16.0 for windows (SPSS, Chicago, IL, USA). The level of significance was set at $P < 0.05$.

Results

The study group comprised 148 (53.1%) males and 226 (46.1%) females with a mean age of 16.6 ± 3.74 years (range: 8–22).

Table 1: Morphologic analysis of orthodontic patients examined for ponticulus posticus

	Male		Female		Total	
	n	%	*n*	%	*n*	%
PP						
Bilateral absent	85	57.4	128	56.6	213	57
Right absent-left complete	2	1.4	2	0.9	5	1.3
Right absent-left partial	4	2.7	8	3.5	11	2.9
Bilateral complete	7	4.7	12	5.3	19	5.1
Right complete-left partial	2	1.4	6	2.7	8	2.1
Right partial-left absent	4	2.7	4	1.8	8	2.1
Right partial-left complete	3	2	5	2.2	8	2.1
Bilateral partial	41	27.7	61	27	102	27.3
			p: 0.000			
Total	148	100	226	100	374	100

n=Number of subjects; PP=Ponticulus posticus

Table 2: Prevalence of ponticulus posticus in 3-dimensional CT images of 374 adolescents

Valid	Right						Left					
	Male		Female		Total		Male		Female		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Absent	91	61.5	138	61.1	229	61.2	89	60.1	132	58.4	221	59.1
Complete	9	6.1	18	8	27	7.2	12	8.1	19	8.4	31	8.3
Partial	48	32.4	70	31	118	31.6	47	31.8	75	33.2	122	32.6
			p: 0.09						*p*: 0.34			
Total	148	100	226	100	374	100	148	100	226	100	374	100

n=Number of subjects

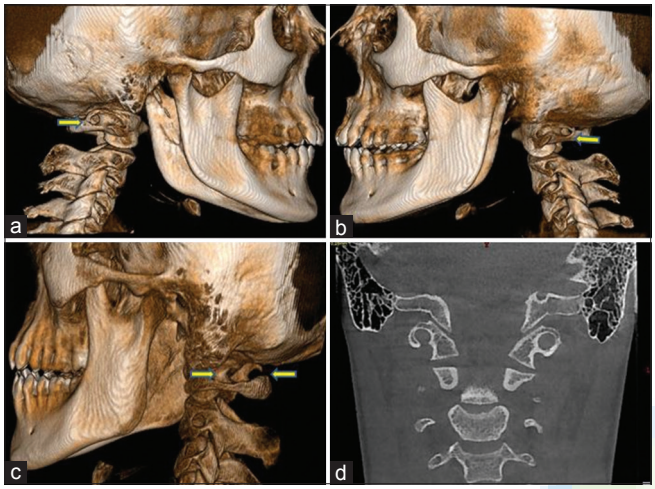

Figure 1: Various morphologic types of ponticulus posticus seen on posterior view of cone-beam computed tomography images (a-c). Bilateral complete (a and b); bilateral partial (c) and complete on the right side and partial on the left (d)

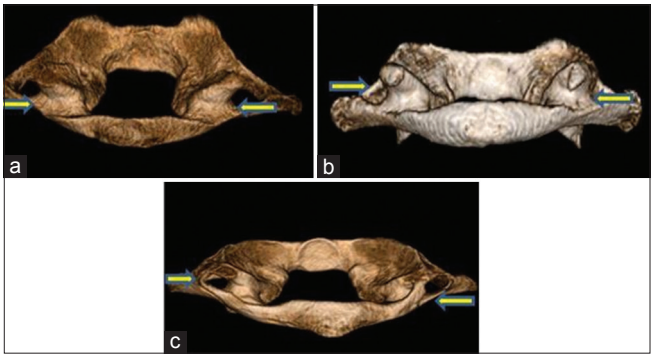

Figure 2: Isolate atlas. Posterior superior view of three-dimensional cone-beam computed tomography image of atlas (normal) (a); oblique (postero-superior and right) view various morphologic types of ponticulus posticus. These perspectives allow a better structural definition of the bilateral partial (b) and bilateral complete (c)

The age of male patients ranged from 8 to 22 (mean ages ± standard deviation, 16.5 years ± 4.29), and the age of female patients ranged from 11 to 22 (16.6 years ± 3.34).

Analyses of 374 three-dimensional CBCT images revealed a PP on one or both side (s) in 161 patients (43%). Of these, 161 patients, 19 had complete bilateral PPs, 102 had partial bilateral PPs, 16 had mixed bilateral PPs, 5 had complete unilateral PPs, and 19 had partial unilateral PPs [Table 1 and Figures 1a-d and 2a-c]. The data indicate that the distribution of the presence of the bony bridge in the first cervical vertebra is higher in females (98 of 226 or 43.3%) than in males (63 of 148 or 42.5%). There was a significant difference in the prevalence between males and females ($P = 0.000$).

Complete and partial PPs were observed on the right side in 7.2% of the male subjects and 31.6% of the female subjects. Complete and partial PPs were observed on the left side in 8.3% of the male subjects and 32.6% of the female subjects. The difference in frequency between the right and left sides between males and females was not statistically significant [Table 2].

Discussion

As stated, we need to better understand the morphologic features and the prevalence of this anomaly considering its growing clinical importance. A PP that appears to be the result of the complete or incomplete ossification of the posterior atlanto-occipital membrane over the vertebral artery groove[18] is a significant abnormality of the atlas in the management of atlantoaxial instability.[10,19] 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 and correlated clinical expressions.[20]

Many terms have been used in the literature to describe the PP anomaly, including sagittal foramen and atlantal posterior foramen, arcuate foramen, a variant of Kimmerle's anomaly, upper retroarticular foramen, canalis vertebralis; retroarticular vertebral artery ring, retroarticular canal, and retrocondilar vertebral artery ring. However, the most commonly accepted name is PP.[4,21,22]

The PP is generally regarded as a simple anatomical variant. However, the compression of the nervous and vascular structures passing through the foramen (vertebral

artery, the periarterial plexus, and the suboccipital nerve) may result in a combination of symptoms such as cervical migraine,[23] neurosensory-type hearing loss,[24] neck pain, vertigo, shoulder/arm pain, and, in some instances, loss of postural muscle tone and consciousness,[25] resulting in vertebrobasilar insufficiency.[18] A severe headache is present in 56–90% of people with PPs.[26,27] A headache, neck and shoulder/arm pain, and vertigo occur with significantly greater frequency in patients with complete PP compared to patients with partial PP.[25] In a radiological survey, Takaaki *et al*.[28] observed that in patients with at least one narrow disc space, the possible occurrence of PP was higher. No correlation was found with other cervical anomalies, such as block vertebrae. This feature was not examined in the present study and requires further investigation.

Inserting a C1LMS is a difficult procedure as the region of atlanto-axial vertebral contains the epidural venous plexus and the greater occipital nerve. Because inserting a C1LMS at the classic entry point at the junction of the posterior arch and the lateral mass[10,18] causes significant bleeding from the epidural plexus and can possibly cause irritation to the C2 nerve root, which results in occipital neuralgia, some surgeons recommend placing the screw higher, starting at the posterior aspect of the posterior arch.[29] The purported benefits include longer bony purchase, increased rigidity, less C2 ganglion manipulation and postoperative neuralgia, and less intraoperative blood loss due to less of a disruption of the perineural venous plexus.[9,11] A broad posterior arch of the atlas is the best indication for this modified screw placement. While this may be reasonable for most patients, in patients with a PP, the anomaly has the possibility of being misidentified as the broad posterior arch. Young *et al*.[12] reported that mistaking the PP for a broad posterior arch of the atlas during C1LMS placement could cause injury to the vertebral artery. The PP can also be mistaken for a broad dorsal arch, and the surgeon may insert the screw into the PP.[4] This can result in an injury to the vertebral artery, which is trapped in the arcuate foramen. Vertebral artery injury may not cause any symptoms if the patient and the surgeon are lucky, but otherwise, it can lead to stroke or even death by thrombosis, embolism, or arterial dissection.[4,30]

In their article, Elliott and Tanweer[3] systematically reviewed and analyzed radiographic, cadaveric, and surgical data and reported on the prevalence of PP. In 44 reports describing the presence of PP in online databases, 21,879 cases (15,542 patients and 6247 bony/cadaver specimens) were included. The overall prevalence of PP was 16.7%, 16.6% in X-ray studies, 17.2% in computed tomography (CT) studies, and 18.8% in cadaver specimens. The anomaly comprised a complete foramen in 9.3% of the cases and an incomplete foramen in 8.7% of the cases. It was found to be bilateral in 5.4% of the cases and unilateral in 7.6% of the cases. The authors found no difference between males and females. They concluded that careful assessment using preoperative multiplanar CT imaging should be performed prior to considering C1LMS implantation. Sharma *et al*.[24] studied the lateral cephalometric radiographs of 858 Indian orthodontic patients aged 8–22 for the presence of PP of the first cervical vertebra. In their study, complete PPs were found in 4.3% of the subjects, with a higher prevalence in males (5.33%; 16 of 300) compared to females (3.76%; 21 of 558). Kendrick and Biggs[13] studied the lateral cephalometric radiographs of 353 young Caucasian orthodontic patients aged 6–17 for the presence of the same entity. Of these subjects, 15.8% showed "some degree" of a PP, with no apparent gender predilection (14.6% males and 16.9% females). The youngest female with a PP was 6 years and 7 months old, and the youngest male with a PP was 6 years and 4 months old. This proves again that age is not a criterion for the formation of a PP. The present study is the first to evaluate the presence of PPs in orthodontic patients using CBCT images. We examined the three-dimensional CBCT images of a Turkish sub-population and were astonished that as much as 43% of the patient population had PPs, as we had not noticed in our daily practice that the prevalence was so high. Therefore, the presence of this anomaly should be carefully checked before screw placement in the lateral mass of the atlas in order to avoid vertebral artery injury.

Most previous studies have been based on lateral radiographs; therefore, it is not typical to determine if the PP is bilateral or unilateral. In the Young *et al*. study,[12] PPs were almost equally detected on both the left and right sides. This was not clearly identified in previous plain radiographic studies because the plain film studies fail to differentiate the right and left. In previous cadaveric studies, there was no difference between the two sides.[14,15] Young *et al*.[12] stated that most of these patients underwent a CT scan because of cervical spine problems. Therefore, these patients did not necessarily represent the whole population. In addition, as these patients required screw fixation at other levels of the cervical spine or the occiput, three-dimensional CT scans would have been helpful in planning the placement of these screws.[12] Further studies, including lateral cephalometric head radiographs, which have been taken in the department of dentistry for the evaluation of dental conditions, and regardless of any cervical symptoms, are needed to investigate the exact prevalence of PP.[23]

Conclusion

Our results suggest that the prevalence of PP is higher than previously believed. Having a PP is not an uncommon anomaly in Turkish orthodontic patients, although its prevalence in other Asian races remains to be investigated.

Because PPs vary widely in shape and size, the presence of this anomaly should be carefully ruled out using lateral radiographs before C1LMS insertion to avoid vertebral artery injury. When a PP is observed or suspected on a lateral radiograph, we recommend that a three-dimensional CBCT scan of a patient who is about to receive a C1LMS be performed.

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Conflicts of interest
There are no conflicts of interest.

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