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Review Article

Review of Ponticulus Posticus, a Bony Anomaly of the Atlas Bone, Using Cone-Beam Computed Tomography and Lateral Cephalograms

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Abstract

Ponticulus Posticus (PP) also known as arcuate foramen, is a bony anomaly that cannot be neglected. Studies have used two-dimensional (2D) lateral cephalograms to determine the prevalence of PP. Only a few have used cone-beam computed tomography (CBCT), a reliable three-dimensional (3D) imaging technique, to investigate this anomaly. Articles about the use of CBCT to determine the prevalence of PP were searched in the PubMed database. This article aims to review PP related researches, which studied the population using CBCT. Seven articles from six countries comprising 2,056 individuals were examined based on the inclusion and exclusion criteria. The average prevalence of PP using CBCT was 34.4% (range, 7% - 42%). The prevalence was higher in those with migraine than in healthy individuals. No significant differences in prevalence were observed based on gender, location (bilateral vs. unilateral), side (left vs. right), and type (partial vs. complete). Agreements in the prevalence and diagnosis between CBCT images and lateral cephalograms were found to be good in most cases; although later, Disparities were encountered in some studies. These findings indicate that a reliable data source can be obtained using 3D imaging techniques to investigate PPs. The prevalence of this anomaly is higher among individuals with migraine. However, it is not significantly associated with age or sex. Despite being able to detect PPs in both lateral cephalograms and CBCT images, the data can be recorded with more precision and detail via CBCT.

Keywords: *Ponticulus Posticus; CBCT; Lateral Cephalogram; Prevalence; Migraine; Artificial Intelligence*

Abbreviations

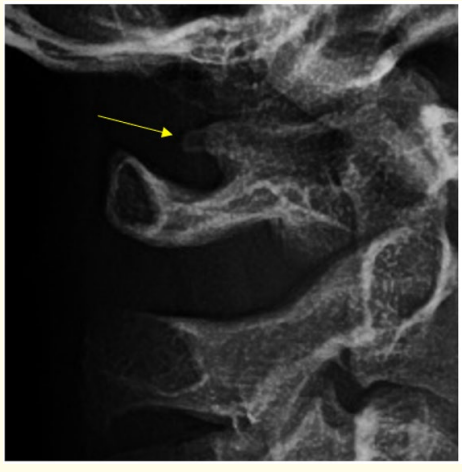
PP: Ponticulus Posticus; CBCT: Cone Beam Computed Tomography; C1: Atlas; C1LMS: C1 Lateral Mass Screw; AI: Artificial Intelligence

Introduction

Atlas, the first cervical vertebra (C1) of the spine, may present with a morphological anomaly called ponticulus posticus (PP), which is characterized by a small posterior bridge between the posterior segment of the superior articular eminence and the posterolateral part of the superior margin of the posterior arch of the atlas. The other names that describe this anomaly include arcuate foramen, foramen arcuate atlantis, posterior ponticle, and Kimerle anomaly [1].

In case of PP presence, it can be formed partially or completely (Figures 1-5) and may form unilaterally or bilaterally (Figure 6 and 7) around the vertebral artery and the first cervical nerve root [2].

Figure 1: *No PP anomaly.*



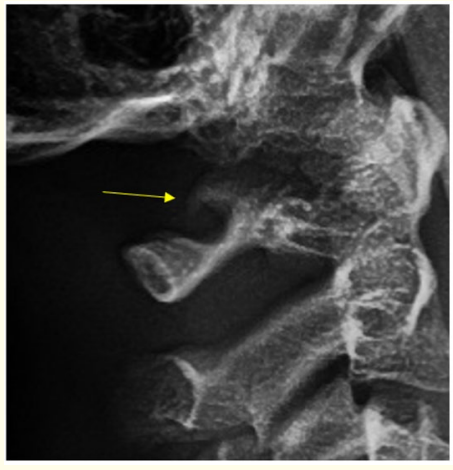


Figure 2-4: *Partial PP with different forms, shown with yellow arrows.*

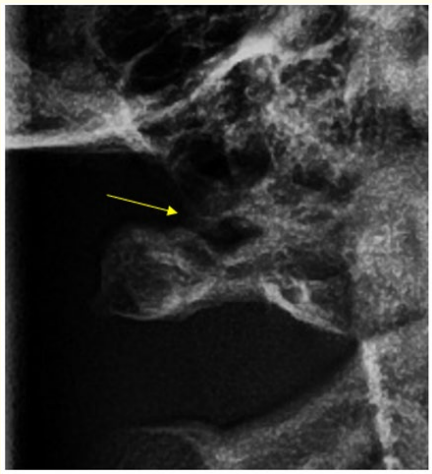


Figure 5 and 6: *More advanced forms of PP encapsulating the vertebral artery.*

Figure 7: *Bilateral PP.*

Lateral cephalograms are widely used to evaluate dental and skeletal variations in an individual. The low radiation dosage and cost-effectiveness make them easy to use in many fields. While lateral cephalograms are used for the conventional measurements, presence of PP anomalies on the atlas may also be evaluated. The use of artificial intelligence (AI) for interpreting cephalograms has been gaining popularity and appears to have promising results [3].

The PP tends to be asymptomatic; therefore, early detection of this anomaly is important. Radiologists and orthodontists may be the first to encounter cases of PP using two-dimensional (2D) or three-dimensional (3D) imaging techniques [4].

Cone-beam computed tomography (CBCT) involves low doses of radiation, requires a short time for imaging, and offers better image resolution than CT. Additionally, it obtains the relevant data from 2D images, such as panoramic and lateral cephalograms [5]. The recent use of AI in CBCT for the automated localization of landmarks in the mandible suggests that AI can automatically segment the mandible, identify anatomic landmarks, and address the demands [6].

In some instances, the PP can compress the V3 segment of the artery, suboccipital nerve, and venous plexus and contribute to the incidence of neurological pathologies [7]. When a PP is observed or suspected on a lateral radiograph, it is recommended to look for other possible symptoms, such as migraine. Further investigative measures using 3D imaging techniques such as CBCT can offer valuable information that may not be detected using 2D imaging techniques. Patients who require a C1 lateral mass screw (C1LMS) would need to undergo a 3D scan of the region before the operation to determine a safer entry point and the right trajectory for screw insertion [8].

PPs are frequently encountered by doctors and dentists and must not be neglected [7]. Recently, a growing number of studies have evaluated the prevalence of PP as a possible predisposing factor for presence of several other conditions, such as migraine, congenital absence of permanent teeth, teeth transposition, canine impaction, head posture, temporomandibular disorders, and skeletal and dental occlusion [9-14].

Aim of the Study

The article aims to review PP articles to gather information about the prevalence, other possible related anomalies, signs, and symptoms using CBCT.

Materials and Methods

Suitable articles on PP were searched using the PubMed database.

The inclusion criteria for the selection of articles were as follows:

1. Studies that included CBCT: Lateral cephalograms cannot precisely indicate whether the PP is unilateral or bilateral and partial or complete. Therefore, studies based on non-CBCT data were disregarded.
2. Studies published from 2009 and later.
3. Articles published in the English language.
4. Original articles that focused on the prevalence of PP.
5. Accessible articles available on PubMed for the scientific community and universities.
6. Studies in which the diagnosis was made by a specialist radiologist and/or in the radiology department: A precise diagnosis, along with the recognition and differentiation of the PP, is important. Therefore, approval by a trained radiologist specialist was desired.

The following articles were excluded from the study:

1. Studies with orthopantomograms or lateral cephalograms that did not include CBCTs in their investigation.
2. Studies with a high number of dropouts.
3. Those with insufficient or inconclusive statistical data.
4. Review articles.

Results

Seven articles from different countries were selected and examined based on these criteria.

An Italian study comprising 220 individuals in the Chieti region reported a PP prevalence of 20.9%, and the prevalence of migraine was 12.272% [15]. The study concluded that early identification of the mutation in the atlas (C1) is important in patients who may be present with frequent headaches and unexplained neurosensory signs and symptoms in the head, neck, and shoulder region.

A Turkish study comprising 181 individuals in Erzurum reported a prevalence of 36.5%, with 43.9% unilateral and 56.1% bilateral PPs; the anomaly was mostly detected in patients with Cl. III occlusion [16].

In another Turkish study comprising 698 individuals in Kayseri, the prevalence of PP identified using CBCT images was 36.8% [17]. The prevalence of bilateral complete PP was 6.3%, bilateral partial was 16.2%, unilateral complete was 6.3%, and unilateral partial was 4.6%. The authors reported a significant dominance of males over females, but no significant difference was noted between the left and right sides.

A comparative Indian study in Odisha evaluated the prevalence of PP on both digital lateral cephalograms and CBCT in 200 individuals, 100 of whom were healthy, and the remaining 100 had migraine headaches [18]. The latter group had a prevalence of 42%, while the prevalence among healthy individuals was 19%. The study reported a "very good" agreement between the lateral cephalogram and CBCT results. However, there were disagreements in three cases, where partial-type PPs were seen on the lateral cephalogram but not verified on the CBCT images.

In a study comprising 200 individuals in Seoul, Korea, a stark difference in the prevalence of PP was observed between the lateral cephalogram and CBCT methods [19]. CBCT confirmed a prevalence of 15.5%, whereas a prevalence of only 6.95% was reported using lateral cephalograms. No significant difference was observed between bilateral and unilateral PPs. Likewise, the distribution of the PP was not significantly different between males and females.

A Danish study conducted in 2013 investigated the reliability of 2D vs. CBCT (3D) imaging among 57 individuals with obstructive sleep apnea. The CBCT results showed a PP prevalence of 31.6% compared to a prevalence of 33.3% using lateral cephalograms. The agreement between the two methods was good (k = 0.64); disagreements were observed among nine patients [20].

A Taiwanese study in Kaohsiung comprising 500 individuals revealed a PP prevalence of 7% using CBCT, with no significant difference based on gender or age [21].

Discussion

Based on the results gathered from the seven studies conducted in Taiwan, Denmark, Korea, India, Turkey, and Italy, a total of 2,056 (500 + 57 + 200 + 200 + 698 + 181 + 220) CBCT images were evaluated with an average PP prevalence of 34.4% (20.9 + 36.5 + 36.8 + 31.6 + 19 + 42 + 15.5 + 31.5 + 7 = 240.8 divided by the number of studies). The prevalence of PP ranged between 7% and 42% and was not associated with age or gender. A good agreement between the CBCT and lateral cephalogram results was reported in the Danish study. Nevertheless, there was a discrepancy between lateral cephalograms and CBCT evaluations that can make a difference, when precise and concise diagnosis of an individual [20]. The Seoul study exhibited very different results, further strengthening the idea that CBCT should be considered when investigating the PP subgroups or when the placement of cervical screws is required [21]. The association between PP and migraine was significant in the studies by Sabir., *et al*. [18] and Marci., *et al* [15]. However, no significant differences were observed between the left and right sides.

Gathering data from different countries and evaluating them can give a more comprehensive view of the prevalence of the anomaly and its associations with other factors. Using CBCT to examine PPs will aid in a more precise diagnosis than lateral cephalograms. When a patient has unexplained headaches due to the PP, treating the cause supersedes the use of pain medication and possibly other treatments. To solve this problem, the practitioner must diagnose the PP accurately and take responsible initiatives to alleviate the pressure caused to structures compressed by the anomaly before proceeding with other treatments.

PP can be frequently observed among populations, and a partial or complete PP does not necessarily require immediate intervention. The presence of a PP is one of many factors that should be considered during evaluation, diagnosis, and planning.

Thus, the new reliable data gathered by CBCT and approved by trained radiologists from seven countries in this study provides a more comprehensive and perhaps diverse look at PPs**.** However, additional qualitative studies from various countries and regions with a higher number of participants can help better understand this condition.

Conclusion

The literature search in this review revealed an average PP prevalence of 34% (range, 7% - 40%) based on CBCT imaging. Thus, the bony anomaly can be frequently present and detected and is not significantly associated with age and gender. The agreement between CBCT images and lateral cephalograms was inconclusive among the studies included in this review. Patients with migraine may have a higher prevalence of PP, which further proves the need for investigations in individuals with unexplained headaches and neurological disorders.

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Conflicts of Interest

There are no conflicts of interest to declare.

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