An exploration of the enigmatic ponticulus posticus: a cone beam computed tomographic study

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SUMMARY

During embryonic development, the activity of neural crest cells has the potential to induce the ossification of the posterior atlantooccipital ligament, resulting in the formation of an abnormal bony bridge known as "Ponticulus Posticus" (PP). The presence of PP increases the likelihood of vertebral artery obstruction, and patients with this condition frequently exhibit symptoms of vertebrobasilar insufficiency. Furthermore, connections have been depicted between PP and dental agenesis, malocclusions, and cleft lip and palate. This study assessed the prevalence, morphology, and superior articular facet (SAF) dimensions in PP using Cone Beam Computed Tomography (CBCT). In this retrospective study, SPSS 22.0 was used to analyse 202 cervical CBCT images devoid of pathologies. PP, age, and sex relationship were examined using the t-test and chi2 analysis. Pearson correlation examined the relationship between PP and non-PP SAF dimensional differences. P values <0.05 were significant. The prevalence of PP was 8.4%, with 64.7% constituting complete type and 35.2% partial type. The unilateral partial group's anteroposterior (D1) and transverse (D2) dimensions showed a strong positive association and significant difference. Understanding this anomaly and the changes it can cause in depth is essential for a clinician to diagnose orofacial pain. Taking into account the benefits of using CBCT enables a detailed evaluation of the vertebral column in three different planes, allowing us to measure the metrical dimensions of SAF precisely in the present study. It can be considered a gold standard in evaluating PP as a diagnostic tool.

Key words: Arcuate foramen – Cone beam CT – Orofacial pain – Atlas

INTRODUCTION

"Atlas", the first cervical vertebra of the spine (C1), derives its name from Greek mythology, in which "Atlas", the son of Titan, was forced to carry the weight of the sky on his shoulders for eternity. Similarly, the Atlanto-occipital joint is the primary element of "head joints" that bears the weight of the skull. (Patil et al., 2016) An anomaly related to the atlanto-occipital region is the PP, which is a malformed bridge at the posterior segment of the superior articular eminence and the posterolat-

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eral part of the superior margin of the posterior arch of the atlas. PP is also known as the arcuate foramen, foramen arcuate atlantis, posterior ponticle, or Kimerle anomaly. (Falah-kooshki et al., 2022) In recent times, such anomalies have been highlighted to have the potential to join the list of those pathophysiologic conditions whose etiologies have confounded diagnosticians.

Significant anatomic structures such as the vertebral artery and the suboccipital nerve are in the vicinity of PP. Any compression of these might cause symptoms such as migraine, vertigo, diplopia, shoulder pain, and neck pain **(**Bayrakdar et al., 2018**)** It was suggested that, due to the attachment PP to the atlanto-occipital membrane and dura mater, the pressure exerted on the dura results in a type of headache seen in migraine. (Sharma et al., 2010) It also causes alterations in the morphometry of SAF, which has an adverse effect on ergonomics. A study conducted by Dhall et al. discovered larger SAF on the PP side compared to the non-PP side of the same individual (unilateral PP), which may have an impact on joint ergonomics (Dhall et al., 1993). Given the limitations of lateral radiographs, such as the inability to observe the extent and completeness, or superimposition of both sides, Computed tomography (CT), and CBCT is the preferred approach. As CBCT offers lower radiation exposure, faster imaging, and better spatial resolution than CT; hence, it is the preferred imaging modality in this scenario. This study was aimed to investigate the prevalence and morphological characteristics of PP and the subsequent difference in dimensions of the SAF using CBCT to understand this atlanto-occipital joint anomaly more precisely.

MATERIALS AND METHODS

A total of 202 CBCT scans of patients with an age range of 20-60 years were included in this retrospective study. The sample size was calculated using quota sampling method and the formula applied was n= (z2) P(1-P)/d2, where n = sample size, z = statistics for the level of confidence, P = expected prevalence, and d = allowable error. The above formula assumed P and d as decimal values, but it would be also correct if they were percentages, with the exception that the term (1-P) in the numerator would become (100-P).

The study received approval from the Institutional Ethical Committee of JSS Dental College & Hospital. (IEC Protocol Number: 09/2023).

Inclusion criteria

1. Superior quality CBCT images depicting the complete face to cervical region.
2. Scans acquired for all oral and maxillofacial diagnostic and treatment purposes excluding any past history of maxillofacial, cervical trauma or anomalies.
3. CBCT scans including all the boundaries of the atlas vertebrae.

Exclusion criteria

1. Subjects with craniofacial osseous abnormalities, or a history of, or evidence of, orthognathic surgery.
2. Subjects with anomalies involving the midface, previous trauma, and surgeries of the midface.

The 202 CBCT scans were taken using the Planmeca Promax 3D Mid CBCT machine with exposure parameters of 94kVp, 14 mA tube current, 27 s scan time, 20*17 cm FOV and 0.4–0.6 µm voxel sizes. Two oral radiologists performed a radiographic examination of the study scans under optimal viewing conditions separately, twice with an interval of two weeks, to rule out any disparity or bias in the interpretation of results.

The axial images were reconstructed to generate multiplanar reformatted coronal and sagittal images. The prevalence and types of PP, i.e., complete or partial, were evaluated bilaterally in sagittal sections. A complete PP was considered as a circumferential bony bridge over the posterior vertebral sulcus of the atlas, (Fig. 1A) and a partial PP was defined when there was a distinct bony spicule downward from the SAF or upward from the posterior arch that did not enclose circumferentially (Fig. 1B). The unilateral or bilateral presence of PP were recorded.

The maximum dimensions of the SAF in the long axis anteroposteriorly (D1) and transversely (D2) were measured by two oral radiologists independently, who were blinded to patient identity and the presence or absence of PP (Fig. 2).

Fig. 1A.- Depicting complete type of Ponticulus posticus.

Fig. 1B.- Depicting partial type of Ponticulus posticus.

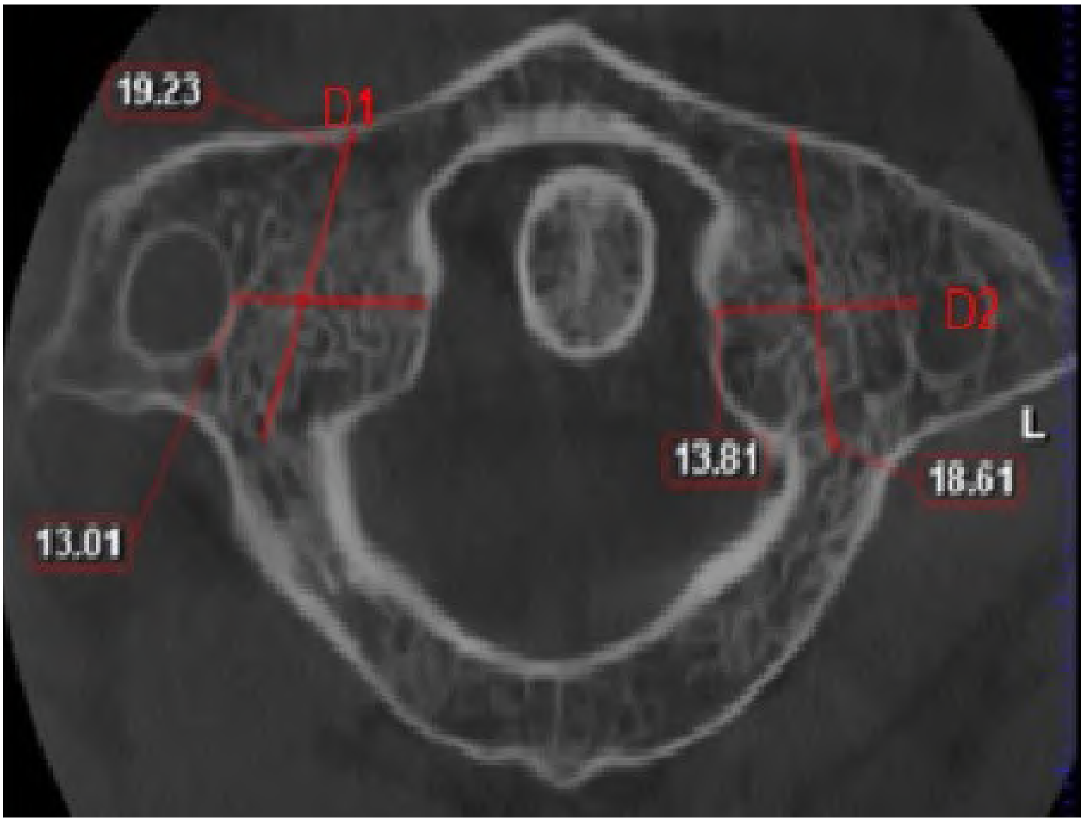

Fig. 2.- Depicting anteroposterior dimension(D1) and transverse dimension (D2) of superior articular facet.

Table 1. Showing prevalence of various types of ponticulus posticus.

Type	Bilateral	Unilateral	
		Right	Left
Partial Ponticulus Posticus (64.7%)	3(50%)	3 (27%)	5(45%)
Complete Ponticulus Posticus (35.2%)	3(50%)	2 (18%)	1(9%)

Statistical analysis

Kolmogorov-Smirnov and Shapiro-Wilk test were done, which revealed that data were normally distributed. Data were analysed using 22.0 version of SPSS software. The relationship among PP, age, and sex was assessed with the t-test and chi^2 analysis, respectively This study used Pearson correlation to evaluate the correlation between the dimension differences of the atlas SAF between PP and non-PP. P values <0.05 were statistically significant.

RESULTS

A total of 202 participants, 101 males and females each, were involved in this retrospective study. The age ranged from 20 to 60 years. Mean age ± std. deviation was 35.16 ± 11.28. When the CBCT scans of 202 patients were evaluated for PP, a prevalence of 8.4% (n=17) was noted, of which 64.7% and 35.2% were of complete and partial type respectively. Within the partial type, 27.2% showed bilateral presentation and 72.7 % were present unilaterally. The complete type, however, was equally distributed unilaterally and bilaterally (Table 1). A two-tailed t-test for independent samples showed that the difference between absence and presence of PP with respect to the dependent variable age was not statistically significant, t (22.95) = 0.7, p = .491, 95% confidence interval (-2.85, 5.77). A Chi^2 test was performed between sex and PP. All expected cell frequencies were greater than 5, thus the assumptions for the Chi^2 test were met. There was no statistically significant relationship between sex and PP χ^2 (1) = 0.06, p = .8, Cramér's V = 0.02.

D1 and D2 results (complete PP side vs non-PP side) (Table 2)

A Pearson correlation was performed to determine if there is a correlation between variables D1(complete pp side) and D1 (complete non-PP side). There was a very high, positive association between D1 and complete pp and non-pp side with r=1. Similarly, there was a very high, positive association between D2(complete PP side) and D2 (complete non PP side) with r=0.92. However, there was no statistically significant correlation (p>0.05).

Table 2. Showing unilateral complete group (n=3).

Dimensions	PP side	Non-PP side	P Value
D1	24.36±2.1	23.99±1.84	>0.05
D2	11.31±0.5	10.7±0.63	>0.05

D1 and D2 results (partial PP side vs partial non-PP side) (Table 3)

A Pearson correlation was performed to determine if there was a correlation between variables D1(partial pp side) and D1 (partial non pp side). There was a very high, positive correlation between variables D1(partial pp side) and D1 (partial non-pp side) with r= 0.87. Similarly, there was a very high, positive association between D2(partial pp side) and D2 (partial non pp side) with r=0.79. A statistically significant correlation was observed between the variables (p<0.05).

Table 3. Showing unilateral partial group (n=8).

Dimensions	PP side	Non-PP side	P Value
D1	22.88 ±1.6	21.29 ±1.64	<0.05
D2	10.6 ±0.52	9.98 ±0.5	<0.05

DISCUSSION

The ponticulus posticus, often known as the "little posterior bridge" because of the ossification and calcification of the posterior atlanto-occipital ligament, is an anomaly often related to neural crest cell activity during foetal development. It has been linked to orofacial pain disorders, migraines, and chronic tension-type headaches. In fact, Putrino et al. in 2018 have stated that in all of these cases, patients' opinions be taken into account, as complications associated with this vertebral defect may necessitate cervical spine surgery. Furthermore, certain variations in the vertebral anatomy such as the presence of the lateral bridge spanning from the lateral mass to the transverse process should essentially be distinguished from the PP (Mann et al., 2016).

The prevalence in the literature has been reported to range from 5.1% to 38.3% (Putrino et al., 2018; Sharma et al., 2010; Falah-kooshki et al., 2022). The prevalence observed in the present study was 8.4%, which aligns with the aforementioned finding (Table 1). The above-referenced prevalence of PP exhibits considerable diversity, mostly influenced by the specific methodology applied in various studies. These methodologies encompass several approaches, such as the examination of fresh or preserved cadaveric tissue, and the employment of radiographic imaging techniques (Hauser and De Stefano, 1989; Pastor et al., 2001). However, the majority of the studies in the literature assessed the prevalence on lateral cephalograms, where it was observed that the prevalence of PP was comparatively lower (Mosavat et al., 2023; Gibelli et al., 2016; Giri et al., 2017; Adisen et al., 2017; Di Venere et al., 2022), as compared to CBCT or CT studies (Bayrakdar et al., 2018; Tripodi et al., 2019; Buyuk et al., 2017; Martiniz et al., 2021; Sekerci et al., 2015). In fact, Kim et al. in 2007 conducted a comparative study between 225 CT scans and 312 LC scans, and found the prevalence of PP to be 26% and 14%, respectively. The observed disparities in the outcomes suggest that the 3D-imaging modality possesses a greater level of sensitivity, potentially leading to a more accurate evaluation of PP. However, Chen et al. in 2015 discovered conflicting outcomes where out of 500 CBCT scans 35 patients (7%) had PP. This result was analogous to the present study (8.4% prevalence). A potential rationale for this observed resemblance may be attributed to ethnic heterogeneity, as stated by Martinez et al. in 2021, who claimed that PP is more prevalent in European and North American populations compared to Asian populations.

The existing body of literature does not provide evidence of a statistically significant difference between males and females (Chen et al., 2015; Bayrakdar et al., 2014). This finding was consistent with the present study (p-value>0.05). However, certain studies showed conflict in gender predilections, where Sharma et al. (2010) presented with female predominance and Martinez et al. (2021) reported male predilection.

This study demonstrated no statistically significant variation in the prevalence of PP in accordance with age (p-value> 0.05). This finding was consistent with the study conducted by Chen et al. (2015), Falah-kooshki et al. (2022) and Hasani et al. (2016). However, Paraskevas et al. (2005) have observed that the gradual mineralization of the PP over time, transitioning from partial to complete ossification, indicates a potential association with the ageing process. Therefore, while ossification may proceed gradually, the presence of PP appears to be a congenital skeletal abnormality of the atlas bone, characterized by various degrees of ossification. The notion could be substantiated by the discoveries of the cartilaginous PP in fetuses and children reported by BG Lamberty et al. (1973).

The SAF establishes an atlantooccipital joint with the occipital condyle, facilitated by the presence of two lateral masses located on the upper surface of the atlas. This joint serves to distribute the weight of the head and enables the movement associated with nodding or shaking the head in a yes or no fashion. The occurrence of dimensional alterations in the articulating surfaces of the atlantooccipital joint results in imbalanced motion within the intervertebral motion segment. Hence, the alterations in ergonomics could potentially be considered as significant contributors to the etiology of migraine, cervical strains, or tension-type headaches (Chen et al., 2015). In the present study, a high positive correlation was noted between D1 and D2 dimensions of SAF of unilateral complete pp side and non pp side, however, the difference was insignificant (p- value >0.05) (Table 2). Whereas, a very high positive correlation and significant difference (p- value<0.05) was noted between D1 and D2 of unilateral partial group (Table 3). This was consistent with the findings of study conducted by Chen et al. (2015). Although the insignificant difference in unilateral complete group could be attributed to small sample size of the present study.

In addition, a multitude of research in the academic literature have established a correlation between PPs and various dental abnormalities. Chitroda et al. (2013) have reported that the presence of PP is associated to a higher incidence of skeletal Class II malocclusion, characterized by mandibular retrusion and an overjet. In a study conducted by Xu et al. (2022), it was found that the presence of PP was associated with an increased prevalence of skeletal Class III malocclusion, characterized by a protruded jaw. Moreover, a study conducted by Sekerci et al. (2015) revealed that the existence of posterior positioning (PP) was linked to an increased occurrence of malocclusions, including overjet, overbite, and crossbite. Further research is required to ascertain the specific mechanisms through which PP may potentially contribute to alterations in skeletal patterns and the development of malocclusions.

Furthermore, Bayradkar et al. (2017) observed a greater prevalence of PP among individuals with cleft lip and palate compared to those without this defect.

Further investigation is required in order to precisely ascertain the specific correlation between PP and the occurrence of cleft lip and palate.

The results of the present study suggest that presence of PP could ultimately alter ergonomics. To the best of our knowledge, this is the first CBCT study conducted on Indian population assessing the difference in dimensions of SAF on PP side and non-PP side in the same individual, elucidating the influence of PP on the dimensions of the SAF. However, further studies with larger sample size and universally accepted criteria to assess partial PP are required and can be a scope for future research, which can aid clinicians in diagnosing orofacial pain with profound accuracy.

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