DOI: 10.4274/gulhane.galenos.2022.02995
Gulhane Med J 2023;65:92-7

Ponticulus posticus in skeletal malocclusions: A lateral cephalometric study

Deepthi Darwin, Subhas Babu, Vidya Ajila, Renita Lorina Castelino, Mohamed Faizal Asan

Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Department of Oral Medicine and Radiology, Mangalore, India

Date submitted:
05.05.2022
Date accepted:
26.10.2022
Online publication date:
15.06.2023

Corresponding Author:
Subhas Babu, Prof. M.D., Nitte (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Department of Oral Medicine and Radiology, Mangalore, India
goginenisb@yahoo.co.in

ORCID:
orcid.org/0000-0001-9383-7886

Keywords: Cephalometry, cervical vertebrae, malocclusion, headache, ponticulus posticus

ABSTRACT

Aims: The ponticulus posticus (PP), a morphological variation in the atlanto-occipital region, is considered a cause of potential entrapment of the vertebral artery segment that traverses the foramen. This study investigated the prevalence and characteristics of PP in different skeletal malocclusion groups using lateral cephalograms.

Methods: This retrospective study evaluated 1,400 lateral cephalometric radiographs of subjects aged between 18-40 years. The radiographs were scrutinized for the presence of PP and its types as partial or complete. We evaluated PP according to gender and skeletal malformations as skeletal class-I, II, or III (determined using Point A - Nasion - Point B angle) by two independent examiners.

Results: The study included 1400 cephalograms from 607 males (43.4%) and 793 females (56.6%). The mean age was 21.96±0.24 years. PP was more common among male subjects (30.9%) compared with the female subjects (p=0.001). It was predominantly observed among the skeletal class-III (27.8%) malocclusion, followed by class-I (23.1%) and class-II (20.6%) malocclusion (p=0.049). Considering the types of PP, the partial form was more frequent among males (71.8%) and females (75.2%).

Conclusions: In this study, the occurrence of PP was observed in 23.5% of the population, predominantly among males. The highest frequency of PP was in the population with skeletal class-III malocclusion.

Introduction

A precise radiographic assessment and interpretation of various anatomic structures are critical as these structures may serve as a nidus to an underlying disease process. In dentistry, lateral cephalogram is one of the most widely used diagnostic radiographs in clinical orthodontics for cephalometric tracings, which can also help analyse any significant pathology of the cervical spine region. One of the important anatomical findings in the cervical spine region is ponticulus posticus (PP), an abnormally deformed bony bridge of the atlas first reported by Macalister in 1893 (1,2). It connects the posterior region of the superior articular process to the postero-lateral region of the superior margin of the posterior arch of the atlas (3). It is assumed to result from the lateral margin of the posterior aspect of atlanto-occipital membrane ossification that varies at different levels (4). Some terminologies for PP include the Arcuate foramen, Kimmerle anomaly, Retroarticular canal, Canalis arteriae vertebralis, Pons posticus, Foramen sagitale, and Foramen atlantoideum (5-8). The association of this structure with disorders such as vertebrobasilar insufficiency, migraine without aura, cervical pain syndrome, sudden sensorineural hearing loss, diplopia, chronic tension-type, and cervicogenic headaches is of great clinical significance (9,10). Often, negligence in the detection of PP may result in serious complications during cervical spine surgical interventions for managing atlantoaxial instability (11).

The origin of PP is associated with the activity of neural crest cells throughout fetal development (12). A major portion of the skull, vertebral column, maxilla, mandible, and dental tissues originated from these pluripotent stem cells. Any anomalies involving the neural tube may raise the likelihood of aberrant development of the skull, vertebral column, and teeth (13,14). Thus, the dentoskeletal aberrations including malocclusions can be linked to abnormalities in the head and neck position, cervical inclination and orthopedic abnormalities (15). To date, various approaches have been used to assess the frequency of PP in different populations, most commonly in cadaveric specimens, dried atlas specimens, and plain radiography (4). A recent meta-analysis by Elliott and Tanweer (11) showed that PP is as common as 16.6% in lateral radiographic studies and 18.8% in cadaveric investigations. Previous studies have examined the prevalence of PP in various cultural groups and its association with other conditions such as cervicogenic headache (16), narrow disc space (17), cleft lip and palate (18), and elongated styloid process (19). However, the data on the prevalence of PP and its radiographic characteristics observed among the various sagittal skeletal patterns and other maxillofacial conditions are sparse. Hence, this study evaluated the association of PP in various skeletal malocclusion groups.

Methods

In this retrospective study, we collected lateral cephalograms of the subjects who had visited the Department of Maxillofacial Radiology [AB Shetty Memorial Institute of Dental Sciences, Constituent College of NITTE (treated as University), Mangalore] from January 2020 to December 2021. Radiographs were screened based on selection criteria. We included lateral cephalograms of subjects aged 18 to 40 years, taken with good diagnostic quality for various diagnostic purposes. A total of 1564 radiographs were obtained to analyse for PP based on the subject's skeletal malformations. The radiographs obtained from the archives underwent quality assessment in terms of dimensional stability and image clarity. However, we excluded 164 radiographs due to poor image clarity, the presence of facial deforming pathologies, evidence of surgical interventions of the maxillofacial skeleton, and radiographic images that had poor visibility of the posterior arch of the atlas (due to overlapping of the occiput or the mastoid region over the area of interest). Radiographs of subjects with any artifacts affecting the craniofacial region were also excluded. The study was performed following the AB Shetty Memorial Institute of Dental Sciences Institutional Ethical Committee approval (Ethics/ABSMIDS/188/2022, date: 21.01.2022).

Image acquisition

The lateral cephalograms were procured with Planmeca ProMax S2-2D (Helsinki, Finland, 2008) under standard imaging techniques with the exposure parameters of 60-84 kV; 5-16 mA, and an average exposure time of 18.7 s. The image analysis was carried out in Planmeca Romexis software (version 2.4.2). Two independent oral and maxillofacial radiologists with a minimum of 10 years of clinical experience evaluated the radiographs. They examined no more than 10 longitudinal sets of graphs at a time to reduce bias caused by fatigue. There were no significant discrepancies in the radiographic interpretation between the two radiologists, and the inter-examiner variability was assessed using the Kappa test.

Image analysis

Lateral cephalometric radiographs were carefully examined under appropriate lighting for the presence of PP, along with the sagittal skeletal patterns of the subjects. In lateral cephalometrics, the ANB angle is a parameter that defines the mutual sagittal relationship between the upper and lower jaws either as orthognathic, mesial, or distal (20). Based on the relationship of Point A - Nasion - Point B (ANB) angle measurements, the anteroposterior skeletal relationship between the maxilla and mandible was categorized as skeletal class-I (with ANB angle of 0-4°), class-II (with ANB angle of >4°) and class-III (with ANB angle of <0°) (21). Further, the morphology of PP was analysed based on the classification given by Lo Giudice et al. (22) as follows:

- Complete type - Presence of a fully extended/completed bony ring above the posterior arch of the atlas (Figure 1A).

- Partial type - The presence of less than a half-extended bone bridge from the condyle to the posterior dental arch (Figure 1B).

- Absence of PP.

Statistical Analysis

Statistical analysis was performed with a Statistical Package for Social Sciences Software (International Business Machines Corporation, Armonk, NY, USA) version 26. The categorical data were represented as percentages and analyzed using the Pearson chi-square test. A p-value of 0.05 was considered statistically significant.

Results

The analyses included 1,564 lateral cephalograms and 1,400 were selected based on the inclusion and exclusion criteria. Table 1 displays the characteristics of the sample. The mean age of the subjects was 21.96±0.24 years, and there were 607 males and 793 females. Table 2 displays the frequency of PP and its types across genders and different skeletal malocclusion. Out of 1,400 radiographs, 329 (23.5%) showed PP, of which 188 (57.1%) belonged to males and 141 (42.9%) belonged to females. There was a statistically significant association between the occurrence of PP and male gender (p=0.001). The partial type (73.3%) was predominant compared with the complete type (26.7%). Although the partial type was more common among females, there was no statistical difference. However, we observed a statistically significant association between PP across different skeletal malocclusion groups (p=0.049). PP was predominantly found in the class-III (27.8%) skeletal malocclusion followed by class-I (23.1%) and class-II (20.6%). The occurrence of the complete form of PP was higher in skeletal class-III (31.3%) followed by class-I (27.8%) and class-II (20.6%) malocclusion. The partial type was predominant in skeletal class-II (79.4%), followed by class-I (72.2%) and class-III (68.7%) malocclusion. However, there was no significant difference between the different types of PP among the skeletal malocclusion groups.

Discussion

Over the last few decades, the relationship between minor atlanto-occipital abnormalities and their clinical impact has gained interest among various specialties, including head and neck surgery and orthopedics. Considering its serious complications in the surgical interventions of the cervical spine, clinicians and maxillofacial radiologists must have an in-depth knowledge of the anatomical variations of the cervical vertebrae and their characteristics using routine imaging modalities for the identification of any pathologies and for establishing an appropriate referral strategy.

The congenital origin of PP from the neural crest cells can be indicated by the presence of lamellar patterns inside the bone matrix, signifying endochondral ossification. PP has been thought to arise from neural crest cells (23,24). However, different theories have also been proposed. According to Geist et al. (25), PP was unlikely to mature as hypertrophic adaption, while Schilling et al. (26) considered it an osteophytic formation to safeguard the passage of the vertebral arteries during head and neck movements.

Our study reported a prevalence rate of 23.5%, which is comparatively higher than the previous studies that reported a rate from 11.5% to 18.8% (27,28). Variations in the prevalence of PP may be associated with the characteristics of the

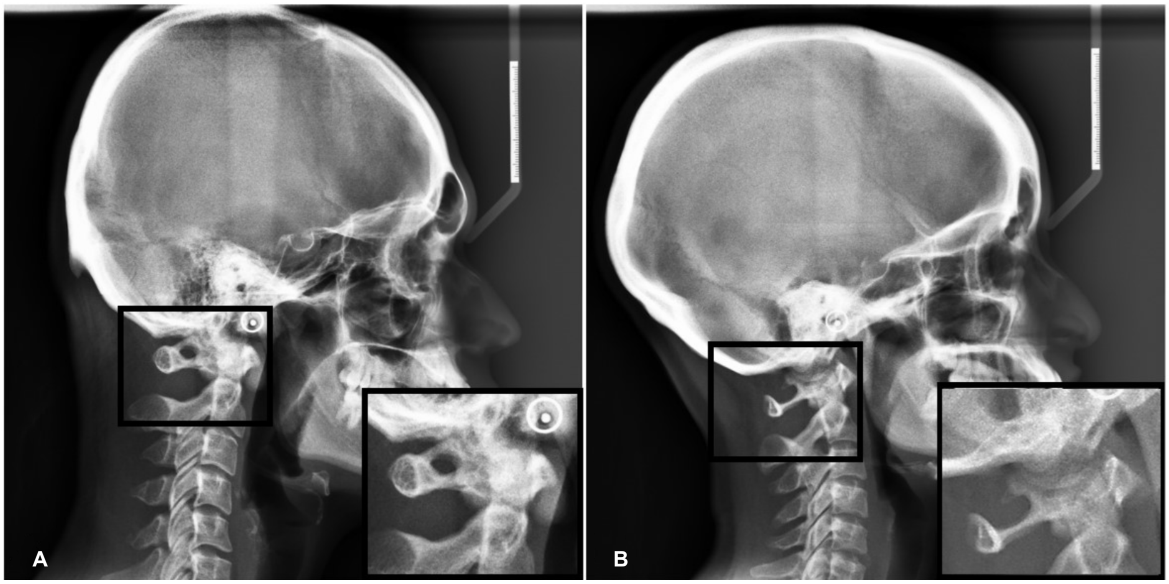

Figure 1. **A)** Lateral cephalogram demonstrating a complete-type ponticulus posticus in the cervical spine region. **B)** Lateral cephalogram demonstrating a partial-type ponticulus posticus in the cervical spine region

Table 1. Characteristics of the study sample		
Total no. of lateral cephalometric radiographs screened		**1,564**
No. of lateral cephalometric radiographs excluded		**164**
No. of lateral cephalometric radiographs included		**1,400**
Characteristics of the radiographs		
Gender	**Total**	**%**
Males	607	43.4
Females	793	56.6
Skeletal malocclusion	**n**	**%**
Class-I	575	41
Class-II	470	33.6
Class-III	355	25.4

Table 2. Frequency of ponticulus ponticus and its types based on gender and skeletal malocclusion

	Ponticulus posticus		Total	p
	Present	**Absent**		
Gender				
Male	188 (30.9%)	419 (69.1%)	607	**0.001**
Female	141 (17.8%)	652 (82.2%)	793	
Malocclusion				
Class-I	133 (23.1%)	442 (76.9%)	575	**0.049**
Class-II	97 (20.6%)	373 (79.4%)	470	
Class-III	99 (27.8%)	256 (72.1%)	355	
	Type of ponticulus posticus		**Total**	**p**
	Complete	**Partial**		
Gender				
Male	53 (28.2%)	135 (71.8%)	188	0.495
Female	35 (24.8%)	106 (75.2%)	141	
Malocclusion				
Class-I	37 (27.8%)	96 (72.2%)	133	0.224
Class-II	20 (20.6%)	77 (79.4%)	97	
Class-III	31 (31.3%)	68 (68.7%)	99	

study population, such as racial and geographic differences. Additionally, radiographic factors like imaging modality and exposure parameters could also lead to variation in the identification of PP (29,30). Considering the variability across gender, the prevalence of PP was statistically significant and more frequent among the male population (57.1%) than females (42.9%). These findings were parallel to the observations of Adisen and Misirlioglu (27), Bayrakdar et al. (31), Geist et al. (25), and Tripodi et al. (32) who also observed a male predominance. This could be attributed to the increased stress exerted on the atlanto-axial junction due to cervical movements (33). We found the partial form of PP to be predominant among the study population; however, we did not find any statistically significant difference between gender and types of PP. Our findings are in agreement with the observations of Chitroda et al. (34) and Pękala et al. (35).

Additionally, we considered the possibility of a relationship between cervical vertebrae aberrations and skeletal malocclusions due to their similar embryologic origin in which the cranial base acts as the linking factor (13,36). The evaluation and classification of orthodontic malocclusion are based on diverse clinical manifestations and cephalometric morphology. The utility of the lateral cephalometric radiographs to precisely evaluate skeletal malocclusions is higher since the skeletal relationship of the maxillar and mandibular arches is not affected by discrepancies in the tooth structure like dental caries and fractures (37). We found skeletal class-I malocclusions more frequent in our study population, followed by class-II and class-III. Our findings are similar to that of Dinesh et al. (38), who also reported class-I as the most predominant type of skeletal malocclusion. We observed PP more prevalent in the skeletal class-III malocclusion groups. The results were in agreement with the findings of Bayrakdar et al. (31) and Sonnesen and Kjaer (14), who have reported an association of morphological abnormalities of the cervical column with increased mandibular overjet. The higher frequency of vertebral body fusion was linked to craniofacial abnormalities in the sagittal plane based on early genetic signals related to the diverse functions of the notochord (39). We analyzed the types of PP among the various skeletal malocclusion groups and found that the partial form was the most common type. The partial type was predominant among the skeletal class-II malocclusion, which is similar to the previous studies by Lo Giudice et al. (22) (3.9%) and Ain et al. (40) (49.5%) (26). Our findings also emphasize the positive correlations between skeletal malocclusion, craniofacial deformities, and cervical vertebral anomalies (1,31).

The clinical importance of PP may be related to surgical concerns in the management of atlantoaxial instability (41). This anomaly of the skeletal column is present in the region of the vertebral artery, greater occipital nerve, and epidural venous plexus, which are all essential neuro-vascular structures (41-43). The intraforaminal segment of the vertebral artery can be severely compressed by PP, resulting in blood flow abnormalities in the vertebral arteries and a spreading deficiency in the inferior branches of the posterior cerebellar arteries (43,44) and increasing the risk of neurological disorders such as Barré-Lieou syndrome, migraine, and vertigo that may cause nausea, vision problems, retro-orbital pain, tinnitus, dizziness, headaches, paralysis of the extremities, and disturbances in swallowing and phonation (9,45). Significant bleeding and occipital neuralgia can result from any vertebral injury inflicted on this region during the atlantoaxial fusion (42,43,45). According to Young et al. (41), the misinterpretation of PP for a broad posterior arch of the atlas during the placement of a lateral mass screw can lead to stroke or even death due to embolism, thrombosis, or arterial dissection due to vertebral artery injury. Furthermore, given the extensive range of osseous involvement in Nevoid Basal Cell Carcinoma Syndrome (NBCCS), the calcification of atlanto-occipital ligament has recently been postulated as an additional radiological finding in NBCCS (46). NBCCS, also known as Gorlin-Goltz syndrome, is a rare multisystemic disease often inherited as an autosomal dominant trait with high penetrance and varied expression (47). Based on the observations from Leonardi et al. (46) and Friedrich (48), a strong association of PP in individuals with NBCCS syndromic patients has been reported. Thus, the understanding of anomalies and pathologies of the craniofacial junction using radiological imaging as a baseline screening tool is essential to assist in the diagnosis and prediction of any likely consequences, which might be beneficial for the patients.

Study Limitations

The current study has an inherent limitation of the inability to evaluate the three-dimensional morphology and symmetry of PP. Although the findings of our study suggest that these radiographs are adequate for screening cervical spine anomalies such as PP, a 3D imaging modality is essential for the accurate diagnosis and morphological evaluation of the skeletal column anomalies.

Conclusion

In conclusion, PP was more common among the skeletal class-III malocclusion groups. Although PP did not show any predilection for a particular age range, male predominance was observed. We also suggest that the possible relationship between the maxillofacial region and vertebra needs to be studied in large-scale future prospective studies as their association is still unclear.

Ethics

Ethics Committee Approval: The study was approved by the Institutional Ethics and Research Committee, AB Shetty Memorial Institute of Dental Sciences, Constituent College of NITTE (treated as University), Mangalore (protocol number: Ethics/ABSMIDS/188/2022, date: 21.01.2022).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: D.D., Design: S.B., R.L.C., Data Collection or Processing: M.F.A., Analysis or Interpretation: S.B., Literature Search: V.A., Writing: D.D.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Sharma V, Chaudhary D, Mitra R. Prevalence of ponticulus posticus in Indian orthodontic patients. Dentomaxillofac Radiol. 2010;39:277-283.
2. Macalister A. Notes on the Development and Variations of the Atlas. J Anat Physiol. 1893;27:519-542.
3. Cho YJ. Radiological analysis of ponticulus posticus in Koreans. Yonsei Med J. 2009;50:45-49.
4. Ahn J, Duran M, Syldort S, et al. Arcuate Foramen: Anatomy, Embryology, Nomenclature, Pathology, and Surgical Considerations. World Neurosurg. 2018;118:197-202.
5. Yochum TR, Rowe LJ. Essentials of skeletal radiology. 3rd ed. Baltimore: Lippincott Williams and Wilkins; 2005:269-270.
6. Le Minor JM, Trost O. Bony ponticles of the atlas (C1) over the groove for the vertebral artery in humans and primates: polymorphism and evolutionary trends. Am J Phys Anthropol. 2004;125:16-29.
7. Crowe HS. The ponticulus posticus of the atlas vertebra and its significance. Upper Cerv Monogr. 1986;4:1-5.
8. Mitchell J. The incidence and dimensions of the retroarticular canal of the atlas vertebra. Acta Anat (Basel). 1998;163:113-120.
9. Wight S, Osborne N, Breen AC. Incidence of ponticulus posterior of the atlas in migraine and cervicogenic headache. J Manipulative Physiol Ther. 1999;22:15-20.
10. Lamberty BG, Zivanović S. The retro-articular vertebral artery ring of the atlas and its significance. Acta Anat (Basel). 1973;85:113-122.
11. Elliott RE, Tanweer O. The prevalence of the ponticulus posticus (arcuate foramen) and its importance in the Goel-Harms procedure: meta-analysis and review of the literature. World Neurosurg. 2014;82:335-343.
12. Putrino A, Leonardi RM, Barbato E, Galluccio G. The Association between Ponticulus Posticus and Dental Agenesis: A Retrospective Study. Open Dent J. 2018;12:510-519.
13. Kjær I. Neuro-Osteology. Crit Rev Oral Biol Med. 1998;9:224-244.
14. Sonnesen L, Kjaer I. Cervical column morphology in patients with skeletal Class III malocclusion and mandibular overjet. Am J Orthod Dentofacial Orthop. 2007;132:427.
15. Lippold C, Danesh G, Hoppe G, Drerup B, Hackenberg L. Sagittal spinal posture in relation to craniofacial morphology. Angle Orthod. 2006;76:625-631.
16. Tambawala SS, Karjodkar FR, Sansare K, et al. Prevalence of Ponticulus Posticus on Lateral Cephalometric Radiographs, its Association with Cervicogenic Headache and a Review of Literature. World Neurosurg. 2017;103:566-575.

17. Takaaki M, Masanori O, Hidenori U, et al. Ponticulusponticus: Its clinical significance. Acta Med Kinki Univ. 1979;4:427-430.

18. Hoenig JF, Schoener WF. Radiological survey of the cervical spine in cleft lip and palate. Dentomaxillofac Radiol. 1992;21:36-39.

19. Sekerci AE, Soylu E, Arikan MP, Aglarci OS. Is there a relationship between the presence of ponticulus posticus and elongated styloid process? Clin Imaging. 2015;39:220-224.

20. Steiner CC. Cephalometrics for you and me. Am J Orthod. 1953;39:729-755.

21. Jacobson A. The 'Wits' appraisal of jaw disharmony. Am J Orthod. 1975;67:125-138.

22. Lo Giudice A, Caccianiga G, Crimi S, Cavallini C, Leonardi R. Frequency and type of ponticulus posticus in a longitudinal sample of nonorthodontically treated patients: relationship with gender, age, skeletal maturity, and skeletal malocclusion. Oral Surg Oral Med Oral Pathol Oral Radiol. 2018;126:291-297.

23. Le Douarin N, LeDouarin NM, Kalcheim C. The Neural Crest. Cambridge University Press, 1999.

24. Matsuoka T, Ahlberg PE, Kessaris N, et al. Neural crest origins of the neck and shoulder. Nature. 2005;436:347-355.

25. Geist JR, Geist SM, Lin LM. A cone beam CT investigation of ponticulus posticus and lateralis in children and adolescents. Dentomaxillofac Radiol. 2014;43:20130451.

26. Schilling J, Schilling A, Galdames IS. Ponticulus posticus on the Posterior Arch of Atlas, Prevalence Analysis in Asymptomatic Patients. Int J Morphol. 2010;28:317-322.

27. Adisen MZ, Misirlioglu M. Prevalence of ponticulus posticus among patients with different dental malocclusions by digital lateral cephalogram: a comparative study. Surg Radiol Anat 2017;39:293-297.

28. Mudit G, Srinivas K, Satheesha R. Retrospective analysis of ponticulus posticus in Indian orthodontic patients-a lateral cephalometric study. Ethiop J Health Sci. 2014;24:285-290.

29. Taşsöker M, Özcan S. Ponticulus posticus: Is it important for a dentist as a radiological finding? Yeditepe Dent J. 2017;13:35-41.

30. Gibelli D, Cappella A, Cerutti E, Spagnoli L, Dolci C, Sforza C. Prevalence of ponticulus posticus in a Northern Italian orthodontic population: a lateral cephalometric study. Surg Radiol Anat. 2016;38:309-312.

31. Bayrakdar IŞ, Miloğlu Ö, Yeşiltepe S, Yılmaz AB. Ponticulus posticus in a cohort of orthodontic children and adolescent patients with different sagittal skeletal anomalies: a comparative cone beam computed tomography investigation. Folia Morphol (Warsz). 2018;77:65-71.

32. Tripodi D, Tieri M, Demartis P, Però G, Marzo G, D'Ercole S. Ponticulus posticus: clinical and CBCT analysis in a young Italian population. Eur J Paediatr Dent. 2019;20:219-223.

33. Panjabi MM, White AA. Basic biomechanics of the spine. Neurosurgery. 1980;7:76-93.

34. Chitroda PK, Katti G, Baba IA, et al. Ponticulus posticus on the posterior arch of atlas, prevalence analysis in symptomatic and asymptomatic patients of Gulbarga population. J Clin Diagn Res. 2013;7:3044-3047.

35. Pękala PA, Henry BM, Pękala JR, et al. Prevalence of foramen arcuale and its clinical significance: A meta-analysis of 55,985 subjects: PS095. Porto Biomed J. 2017;2:190.

36. Sonnesen L. Associations between the Cervical Vertebral Column and Craniofacial Morphology. Int J Dent. 2010;2010:295728.

37. Afrand M, Ling CP, Khosrotehrani S, Flores-Mir C, Lagravère-Vich MO. Anterior cranial-base time-related changes: A systematic review. Am J Orthod Dentofacial Orthop. 2014;146:21-32.

38. Dinesh RB, Arnitha HM, Munshi AK. Malocclusion and orthodontic treatment need of handicapped individuals in South Canara, India. Int Dent J. 2003;53:13-18.

39. Arntsen T, Sonnesen L. Cervical vertebral column morphology related to craniofacial morphology and head posture in preorthodontic children with Class II malocclusion and horizontal maxillary overjet. Am J Orthod Dentofacial Orthop. 2011;140:1-7.

40. Ain QU, Gilani SB, Chaudhary AG, Awan BY. Prevalence of Ponticulus Posticus in Orthodontic Patients of the local population of Islamabad, Pakistan. J Islam Int Med Coll. 2019;14:142-145.

41. Young JP, Young PH, Ackermann MJ, Anderson PA, Riew KD. The ponticulus posticus: implications for screw insertion into the first cervical lateral mass. J Bone Joint Surg Am. 2005;87:2495-2498.

42. Ma XY, Yin QS, Wu ZH, Xia H, Liu JF, Zhong SZ. Anatomic considerations for the pedicle screw placement in the first cervical vertebra. Spine (Phila Pa 1976). 2005;30:1519-1523.

43. Tubbs RS, Johnson PC, Shoja MM, Loukas M, Oakes WJ. Foramen arcuale: anatomical study and review of the literature. J Neurosurg Spine. 2007;6:31-34.

44. Vaněk P, Bradáč O, de Lacy P, Konopková R, Lacman J, Beneš V. Vertebral artery and osseous anomalies characteristic at the craniocervical junction diagnosed by CT and 3D CT angiography in normal Czech population: analysis of 511 consecutive patients. Neurosurg Rev. 2017;40:369-376.

45. Limousin CA. Foramen arcuale and syndrome of Barre-Lieou. Its surgical treatment. Int Orthop. 1980;4:19-23.

46. Leonardi R, Santarelli A, Barbato E, et al. Atlanto-occipital ligament calcification: a novel sign in nevoid basal cell carcinoma syndrome. Anticancer Res. 2010;30:4265-4267.

47. Gorlin RJ. Nevoid basal-cell carcinoma syndrome. Medicine (Baltimore). 1987;66:98-113.

48. Friedrich RE. Ponticulus posticus is a frequent radiographic finding on lateral cephalograms in nevoid basal cell carcinoma syndrome (Gorlin-Goltz syndrome). Anticancer Res. 2014;34:7395-7399.