Partial Atlanto-Occipital Assimilation in a Dry Human Skull: An Osteological Case Report and Clinical Implicationspy

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ABSTRACT

Background: Atlanto-occipital assimilation, also termed occipitalization of the atlas, is a congenital craniovertebral junction anomaly characterized by partial or complete bony fusion of the atlas (C1) with the occipital bone. Although many individuals remain asymptomatic, such fusion can alter the anatomy of the foramen magnum and predispose to atlantoaxial instability and neurovascular compromise in some patients.

Case description: During routine osteology teaching in the Department of Anatomy, AIIMS Guwahati, a dry adult human skull with an attached atlas vertebra was found to exhibit partial fusion between the atlas and the occipital bone. Fusion involved the anterior arch of the atlas and the anterior and lateral margins of the foramen magnum, while the posterior margin remained unfused. The anteroposterior and transverse diameters of the foramen magnum measured 3.2 cm and 3.0 cm respectively, lying toward the lower end of reported normal adult ranges. Three distinct foramina were observed: a right posterior condylar foramen, an accessory anterior tunnel-like foramen between the fused anterior arch and the anterior margin of the foramen magnum, and bilateral intervertebral foramina for the first cervical nerve.

Conclusion: This specimen represents a combined anterior and lateral partial occipitalization. Despite near-normal linear dimensions of the foramen magnum, the altered bony configuration around the craniovertebral junction could have important clinical implications in vivo, particularly for radiological interpretation and surgical planning.

Keywords: *atlanto-occipital assimilation; occipitalization; atlas; foramen magnum; craniovertebral junction; anatomical variation*

INTRODUCTION

The occipital bone forms the posterior part of the cranial vault and contributes to the cranial base, surrounding the foramen magnum. The atlas (C1) articulates with the occipital condyles at the paired atlanto-occipital joints, allowing flexion-extension and limited lateral flexion of the head. [1,2]

Atlanto-occipital assimilation (occipitalization of the atlas, occipitocervical synostosis) is defined as a congenital partial or complete bony fusion between the atlas and the occipital bone.[3] It is believed to result from failure of segmentation between the caudal occipital and cranial first cervical sclerotomes during early embryogenesis. [3,4] The reported incidence in osteological and radiological series is low but consistent, generally below 1% in the general population. [3-5]

Most individuals with atlanto-occipital assimilation are asymptomatic, and the anomaly is often detected incidentally on imaging or during anatomical study. [3,5] However, when associated with reduction in the space available for the spinal cord, atlantoaxial instability, basilar invagination or anomalous vertebral arteries, affected patients may present with neck pain, cervicogenic headache, myelopathy or vertebrobasilar insufficiency. [3-6]

This report describes an osteological case of partial atlanto-occipital assimilation identified in a teaching skull from North-East India, documents its morphometric features and foraminal pattern, and discusses the potential clinical implications with reference to the existing literature.

CASE REPORT

During a routine osteology session in the Department of Anatomy, AIIMS Guwahati, an adult human skull with an attached atlas vertebra was noted to show abnormal fusion at the craniovertebral junction. The age and sex of the specimen were unknown. The calvaria and facial skeleton appeared otherwise normal on gross inspection.

Foramen magnum morphometry

The dimensions of the foramen magnum were measured using a Vernier caliper. The anteroposterior diameter (basion-opisthion) was 3.2 cm, and the maximum transverse diameter was 3.0 cm. These measurements lie within the lower end of the normal adult range reported in morphometric studies of the foramen magnum. [7,8] There was no obvious gross narrowing or irregular encroachment into the foramen magnum ring.

Pattern of fusion

Detailed inspection of the craniovertebral region revealed the following features. There was bony fusion between the anterior arch of the atlas and the anterior margin of the foramen magnum, including the anterior aspect of the occipital condyles. Fusion extended to involve the lateral masses of the atlas and the lateral margins of the foramen magnum on both sides. The posterior margin of the foramen magnum remained free, with no bony union between the posterior arch of the atlas and the squamous part of the occipital bone.

Thus, the anomaly was consistent with partial rather than complete atlanto-occipital assimilation.

Foraminal configuration

Three distinct types of foramina were observed in relation to the craniovertebral junction:

1. Right posterior condylar foramen

A well-formed posterior condylar foramen was present posterior to the right occipital condyle. In vivo, such foramina commonly transmit an emissary vein connecting the sigmoid sinus to the suboccipital venous plexus, and may sometimes convey a meningeal branch of the occipital artery. [1,9]

2. Accessory anterior foramen

An accessory, tunnel-like foramen was present between the fused anterior arch of the atlas and the anterior margin of the foramen magnum. In the absence of soft tissues, it was not possible to identify its exact contents, but it likely corresponded to a space related to the anterior atlanto-occipital membrane and adjacent vascular or fibrous structures. [3]

3. Bilateral intervertebral foramina for the first cervical nerve

On both sides, distinct openings were seen between the posterior aspect of the lateral masses of the atlas and the occipital bone, consistent with the intervertebral foramina for the C1 spinal nerves. Because of the partial fusion, the shape and orientation of these foramina appeared altered when compared with typical atlas-occiput relationships. [3,5]

The axis (C2 vertebra) and lower cervical vertebrae were not present with this specimen, and hence the status of the atlantoaxial joint and lower cervical spine could not be assessed. No other obvious abnormalities of the cranial base such as occipital vertebrae or cleft defects were identified.

As this observation is based on a dry, anonymized skull from an osteology collection, no patient identifiers or clinical data were available, and ethical approval or consent were not required.

FIGURES AND IMAGES

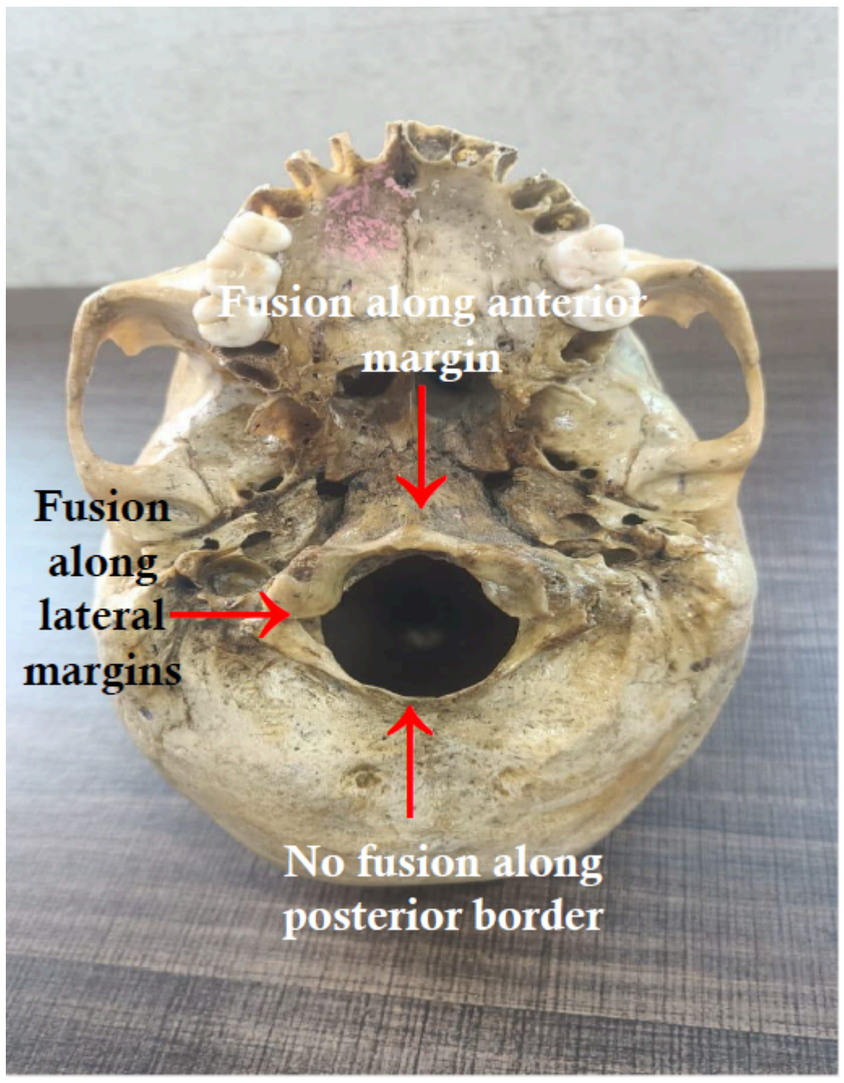

Figure 1. Inferior view of the cranial base of the dry skull showing partial atlanto-occipital assimilation. Bony fusion is evident between the anterior arch of the atlas and the anterior margin of the foramen magnum (vertical arrow), as well as along the lateral margins where the lateral masses of the atlas blend with the occipital condylar region (horizontal arrows). The posterior border of the foramen magnum remains free of fusion (lower arrow), consistent with partial rather than complete occipitalization of the atlas.

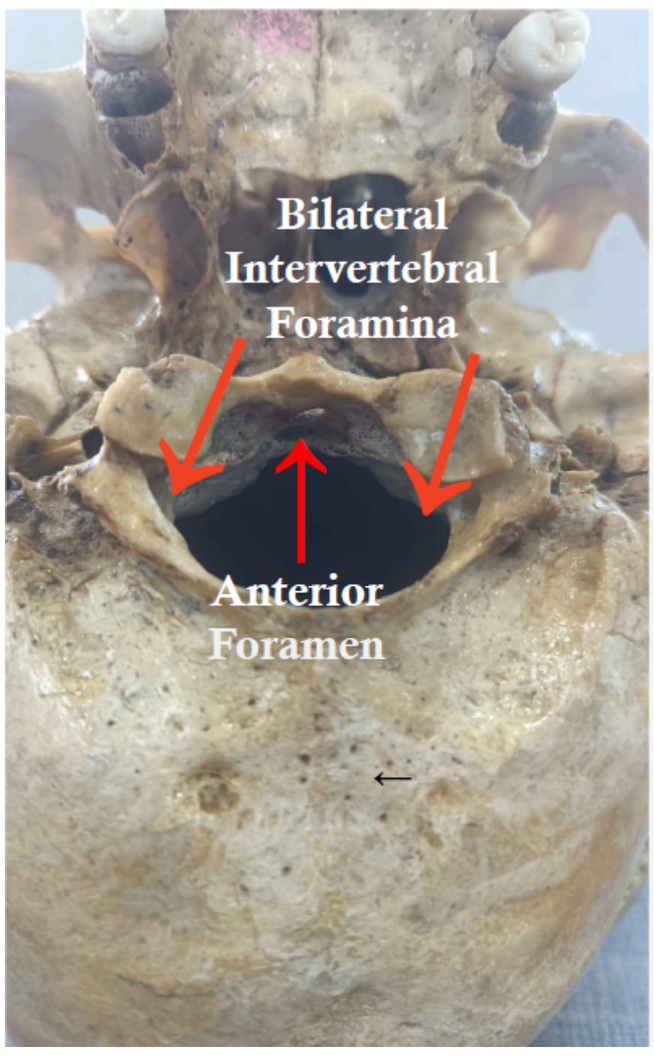

Figure 2. Close-up inferior view of the craniovertebral junction in the same skull demonstrating the altered foraminal architecture produced by partial atlanto-occipital assimilation. Bilateral intervertebral foramina are seen between the fused lateral masses of the atlas and the occipital bone (lateral arrows), representing the exit pathways for the C1 spinal nerves. An additional tunnel-like anterior foramen (central arrow) is formed between the fused anterior arch of the atlas and the anterior margin of the foramen magnum.

DISCUSSION

Embryological basis and etiology

Atlanto-occipital assimilation is classically attributed to a failure of segmentation between the caudal occipital and cranial cervical sclerotomes during the fourth week of intrauterine life. [3,4] This results in fusion between elements destined to form the occipital bone and the atlas. The severity of fusion can vary from subtle partial involvement of one arch to complete occipitocervical synostosis. [3,4]

Although classically regarded as congenital, similar patterns of fusion may occasionally arise secondary to degenerative disease, trauma or infection. [3] Distinguishing congenital from acquired fusion in an isolated dry skull is inherently difficult; however, the smooth, continuous nature of the fusion in this specimen, without irregular proliferative changes, favours a congenital origin.

Morphologic classification

Gholve et al. proposed a morphologic classification of atlanto-occipital assimilation based on the segments of the atlas involved: zone 1 (anterior arch), zone 2 (lateral masses), zone 3 (posterior arch), and a combined type when more than one zone is fused. [4]

In the present skull, fusion involves the anterior arch of the atlas with the anterior rim of the foramen magnum (zone 1), and the lateral masses with the lateral margins of the foramen magnum (zone 2), while the posterior arch remains unfused (zone 3 spared). This pattern corresponds to a combined zone 1 partial occipitalization under Gholve's classification. [4] Similar patterns have been reported in osteological series from India and other populations. [5,10]

Foramen magnum morphometry and space available

The anteroposterior (3.2 cm) and transverse (3.0 cm) diameters of the foramen magnum in this specimen are comparable to values documented in morphometric studies of normal skulls, in which mean anteroposterior diameters of approximately 3.1and 3.3 cm and transverse diameters of 2.7 and 3.0 cm have been reported. [7,8]

This observation challenges a common implicit assumption that atlanto-occipital assimilation invariably leads to a markedly "stenosed" foramen magnum. Linear measurements alone, however, do not fully reflect the three-dimensional space available for the brainstem, upper cervical cord and vertebral arteries. Focal bony encroachments, altered curvature, and dynamic changes during head movement can all influence functional canal dimensions in vivo. [3,6,7] Consequently, it would be inappropriate to infer cord compression solely from the presence of assimilation in the absence of clinical and radiological correlation. Association with atlantoaxial instability and other anomalies

Association with atlantoaxial instability and other anomalies

Clinical and radiological series demonstrate that atlanto-occipital assimilation may coexist with atlantoaxial instability, basilar invagination, block vertebrae and other congenital anomalies of the cervical spine. [3–6] In some studies, more than half of symptomatic patients with occipitalization had radiological evidence of atlantoaxial instability. [4,6] Nevertheless, this represents an increased risk, not a certainty; many individuals with assimilation remain asymptomatic throughout life. [3,5]

In the present osteological specimen, the absence of the axis and lower cervical vertebrae precludes any assessment of atlantoaxial alignment, canal diameter or basilar invagination. Any attempt to reconstruct specific clinical manifestations in the original individual would therefore be speculative.

Neurovascular and surgical implications

The craniovertebral junction is a complex region traversed by the medulla, upper cervical cord, vertebral arteries, venous sinuses and cranial nerves. Variations introduced by atlanto-occipital assimilation have important implications for both radiological interpretation and surgical approaches.

Partial or complete fusion may alter the course of the vertebral arteries in relation to the atlas and occiput, potentially narrowing the vertebral artery groove or displacing the vessel. [6,7] This can increase the risk of vascular injury during posterior fossa decompression, occipitocervical fusion or far-lateral approaches to foramen magnum lesions if the anomaly is not recognized pre-operatively. [6,7]

Similarly, changes in the configuration of the intervertebral foramina for the C1 nerve, as seen in this specimen, may modify the relationship of the nerve to surrounding bony landmarks, again with implications for surgery and regional anaesthesia. [3,6]

The presence of a posterior condylar foramen, as observed on the right side in this skull, is also relevant. These emissary foramina may transmit sizable veins and, if unanticipated, can be a source of troublesome bleeding during suboccipital craniotomy or posterior fossa procedures. [1,9]

Comparison with previously reported osteological cases

Several authors have described atlanto-occipital assimilation in dry skulls, often discovered in teaching collections. [5,10] These reports document a range of patterns, including isolated anterior or posterior arch fusion, unilateral fusion, and complete ring fusion around the foramen magnum. [5,10] Some series also report associated asymmetries of the occipital condyles and variable expression of posterior condylar and other accessory foramina. [9,10]

The present specimen aligns with these observations in demonstrating partial fusion, but is noteworthy for combining both zone 1 and zone 2 fusion with preservation of the posterior arch, and for having near-normal linear dimensions of the foramen magnum. For clinicians, this underscores the importance of avoiding oversimplified assumptions that “any occipitalization necessarily produces severe stenosis,” and instead emphasizes careful correlation between anatomical variation, imaging appearances and clinical findings.

CONCLUSION

From a clinical standpoint, the key implications are that the fusion pattern corresponds to a combined zone 1–2 partial occipitalization, as per Gholve’s classification, and that although such anomalies are associated with an increased likelihood of atlantoaxial instability and neurovascular variations, they are not automatically symptomatic and require individual assessment with detailed imaging and clinical correlation.[3–6] Furthermore, the altered foraminal architecture around the craniovertebral junction, including variation in the C1 intervertebral foramina and the presence of posterior condylar foramina, has important implications for radiologists and neurosurgeons when planning interventions in this region. [3,6,9] This case therefore reinforces the importance of recognizing atlanto-occipital assimilation as a spectrum of variants and highlights the need for meticulous anatomical and radiological evaluation in patients with craniovertebral junction pathology.

REFERENCES

1. Datta AK. Essentials of Human Anatomy: Head and Neck. 6th ed. Kolkata: Current Books International; 2017.

2. Singh V. Textbook of Anatomy: Head, Neck and Brain. 4th ed. New Delhi: Elsevier India; 2023

3. Menezes AH. Craniovertebral junction anomalies: diagnosis and management. Semin Pediatr Neurol. 1997;4(3):209-223.

4. Gholve PA, Hosalkar HS, Ricchetti ET, Pollock AN, Dormans JP, Drummond DS. Occipitalization of the atlas in children: morphologic classification, associations, and clinical relevance. J Bone Joint Surg Am. 2007;89(3):571-578.

5. Mudaliar RP, Shetty S, Nanjundaiah K, Kumar JP, Jetti R. An osteological study of occipitocervical synostosis and its embryological and clinical significance. J Clin Diagn Res. 2013;7(9):1835-1837.

6. Menezes AH. Craniovertebral junction abnormalities. In: Winn HR, editor. Youmans Neurological Surgery. 6th ed. Philadelphia: Elsevier; 2011. p. 1925-1960.

7. Kanodia G, Parihar V, Parihar A, Damke U, Bhambwani K. Morphometric analysis of posterior fossa and foramen magnum. J Neurosci Rural Pract. 2012;3(3):261-266.

8. Burdan F, Szumilo J, Dudka J, et al. Morphology and morphometry of the foramen magnum in human skulls. Folia Morphol (Warsz). 2012;71(4):205-216.

9. Wysocki J, Reymond J, SkarzyÅ„ski H, Wysocki S. The size of selected human skull foramina in relation to skull capacity. Folia Morphol (Warsz). 2006;65(4):301-308.

10. Gopal K, Choudhary AK, Agarwal J, Ali S. Morphological status of assimilated atlas vertebra with occipital bone and its clinical significance. Int J Res Med Sci. 2015;3(2):420-424.