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Morphology and Frequency of Occurrence of Ossification of Pterygospinous Ligament in Dry Skulls: A Cross-Sectional Study with Clinical Significance and Phylogenetic Context

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ABSTRACT

Background: The pterygospinous ligament stretches from the spine of the sphenoid to the pterygospinous process. The ossification of this ligament creates a bony bridge that encloses the pterygospinous foramen, referred to as Civinini's foramen. These bony modifications hold clinical significance owing to their relationship with the mandibular nerve and adjacent structures. This study was aimed at ascertaining the occurrence, laterality, and anatomical relationship of pterygospinous bars with the foramen ovale in dry adult human skulls.
Materials and Methods: This study was carried out on 50 dry adult human skulls of unknown sex obtained from the Anatomy Department of the Ananya College of Medicine and Research, Gandhinagar; and from the GMERS Medical College, Himmatnagar, Gujarat. Skulls with damaged cranial bases were excluded. Every skull was carefully examined for the presence of either complete or incomplete pterygospinous bars. The side of the occurrence and the relation of the bar with the foramen ovale were observed. Photographic documentation was created, and the results have been compared with previous study data.
Results: Pterygospinous bars were identified in 5 of 50 skulls, resulting in a total prevalence of 10%. Complete ossification was observed in 2 skulls (4%) and incomplete ossification in 3 skulls (6%). All bars were unilateral, featuring 2 on the right and 3 on the left. No occurrences of bilateral cases were identified. In all the five skulls, the bar was located lateral to the foramen ovale.
Conclusion: The frequency of occurrence of pterygospinous ligament ossification in the present study aligns with findings from previous literature. Awareness of these variances may have potential clinical implications.

Keywords: Pterygospinous ligament, Pterygospinous foramen, Civinini foramen, Mandibular nerve, Ossification, Skull base

INTRODUCTION

The human skull, the most specialized part of the axial skeleton, has long fascinated anatomists and anthropologists. Over the decades, sporadic investigations of the skull have been conducted, but few have focused

on the individual cranial bones and their ligamentous connections.[1] The sphenoid bone is so named from the wedge-like position between the frontal, temporal and occipital bones in the base of the skull, where it lies with its long axis placed transversely. The sphenoid bone consists of a central portion or body, greater and lesser wings, and a pterygoid process on each side. Each pterygoid process descends perpendicularly from the junction of the body and greater wing and is composed of medial and lateral plates. The lateral pterygoid plate is shorter and broader than the medial plate and extends posteriorly and slightly laterally. Its posterior border typically exhibits a sharp projection in its upper part, known as the pterygoid spine. The pterygospinous ligament extends posteriorly and laterally from this spine to the spine of the sphenoid. [2] In 1835, the Italian anatomist Civinini reported that the pterygospinous ligament may undergo varying degrees of ossification. Complete ossification of the ligament results in a bony connection between the pterygoid plate and the base of the sphenoid spine, thereby forming one or more foramina known as the pterygospinous foramina or foramina of Civinini. These foramina transmit branches of the mandibular nerve supplying the temporalis, masseter, and lateral pterygoid muscles. Completely ossified connection is called pterygospinous bar. [3,4]

The precise cause of ossification is not fully understood; nonetheless, these formations are noted to be more prevalent in males and tend to arise unilaterally rather than bilaterally.[1] Presence of ossified ligaments has significant clinical implications as they may impede surgical access to crucial structures.[5] Among cranial ligaments, the pterygospinous and pterygoalar ligaments are clinically significant due to their proximity to the foramen ovale. The pterygospinous bar is usually inferior or medial to the foramen ovale, while the pterygoalar bar is usually lateral or passes under it, sometimes dividing foramen ovale into two compartments.[6] However, considerable variation in their spatial relationships to the foramen ovale has been reported. So, attachment sites are a more reliable criterion than the position relative to the foramen ovale for identifying which ligament has ossified.[7] Although a causal relationship has not been established, ossification of the pterygospinous ligament has been suggested as a potential anatomical factor contributing to mandibular nerve entrapment and may have implications for procedures performed through the foramen ovale in the management of trigeminal neuralgia.[8] Ossification of the pterygospinous ligament can alter the anatomy of the infratemporal region, potentially entrapping branches of the mandibular division of the trigeminal nerve and complicating percutaneous procedures involving the foramen ovale.[9] An ossified pterygospinous bar may make thermocoagulation of trigeminal ganglion difficult or impossible, and it may compress motor branch result in muscle weakness or paralysis, while sensory branch compression can cause neuralgia or paresthesia.[10, 11]

Thus, this study explored the prevalence, morphology, and variability of pterygospinous ossification and its possible anatomical and surgical consequences at the cranial base.

MATERIALS & METHODS

The present study was conducted on 50 dry adult human skulls of unknown sex obtained from the Anatomy Department of Ananya College of Medicine and Research, Gandhinagar and GMERS Medical College, Himmatnagar, Gujarat from September 2024 to January 2026.

Both authors independently observed and verified the presence of a complete or incomplete pterygospinous bar in the cranial base of each skull. The pterygospinous and pterygoalar bars were distinguished largely by their anatomical attachments and not solely by their relation to the foramen ovale alone. When the ossified plate extends between the pterygoid spine and sphenoid spine it was termed the pterygospinous bar;

when it extends between the pterygoid spine and the infratemporal surface of the greater wing of the sphenoid without attachment to the sphenoid spine it was termed the pterygoalar bar. If pterygospinous bar reaches up to sphenoid spine, it was regarded to be complete and if it does not reach sphenoid spine, it was thought to be incomplete. Incomplete bars were classified as pterygospinous or pterygoalar on the basis of their direction from the pterygoid spine to the sphenoid spine or the greater wing of the sphenoid, respectively.

The side of occurrence (right, left or bilateral) and the anatomical relationship of the bar to the foramen ovale (medial, lateral or inferior) were recorded. All the findings were documented photographically with a digital camera. Data were reported as frequency and percentage. The results were compared with the previously published studies for the anatomical variations and clinical relevance.

RESULT

In total, 50 dry adult human skulls were examined. Pterygospinous bars were seen in 5 skulls with an overall occurrence of 10%. 2 skulls (4%) had complete ossification of the pterygospinous ligament out of the 5 skulls (Figure 1). In all these cases there was a well-defined pterygospinous foramen. Complete bars were unilateral, 1 on the right and 1 on the left. No bilateral occurrence of pterygospinous bar was identified.

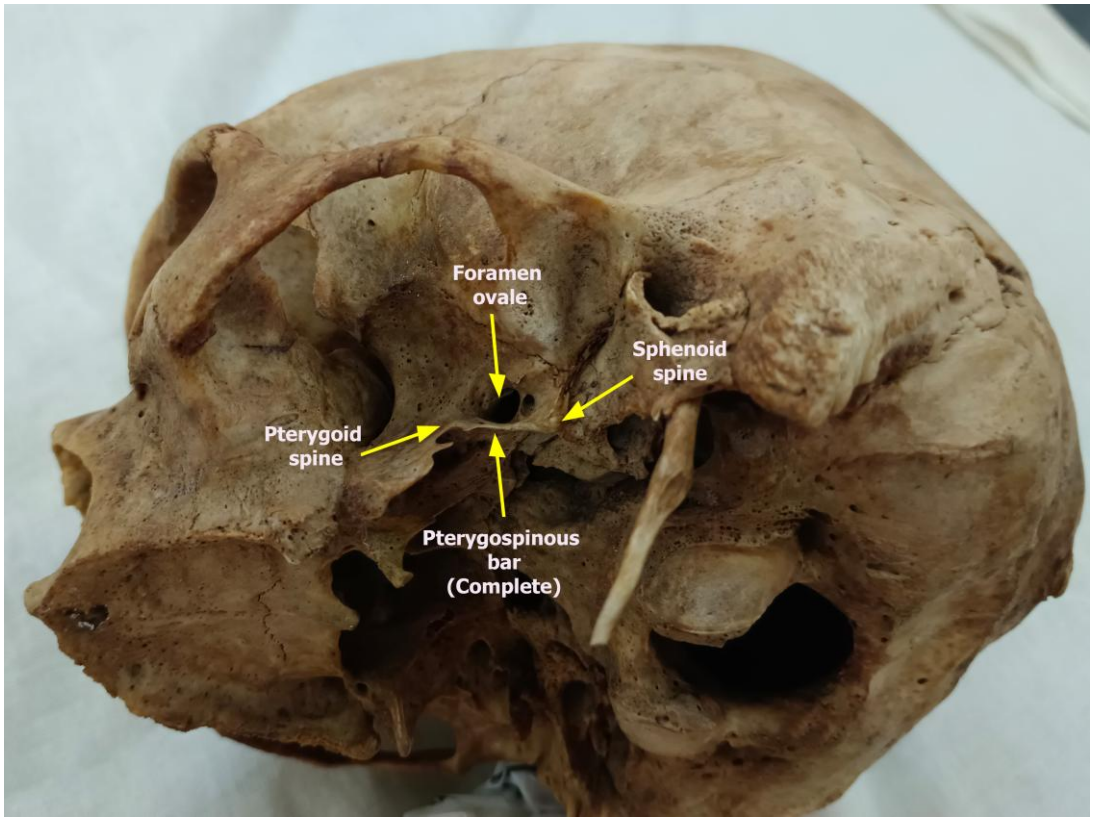

Figure 1. Complete pterygospinous bar on the left side. The bar is lateral to the foramen ovale

Incomplete ossification was reported in three skulls (6%). In such circumstances a partial pterygospinous foramen was formed (Figure 2). Of the 3 skulls with incomplete bars, 2 had left sided and 1 had right side involvement. No bilateral incomplete bars were observed.

In all the 5 skulls with pterygospinous bars the bar was lateral to the foramen ovale.

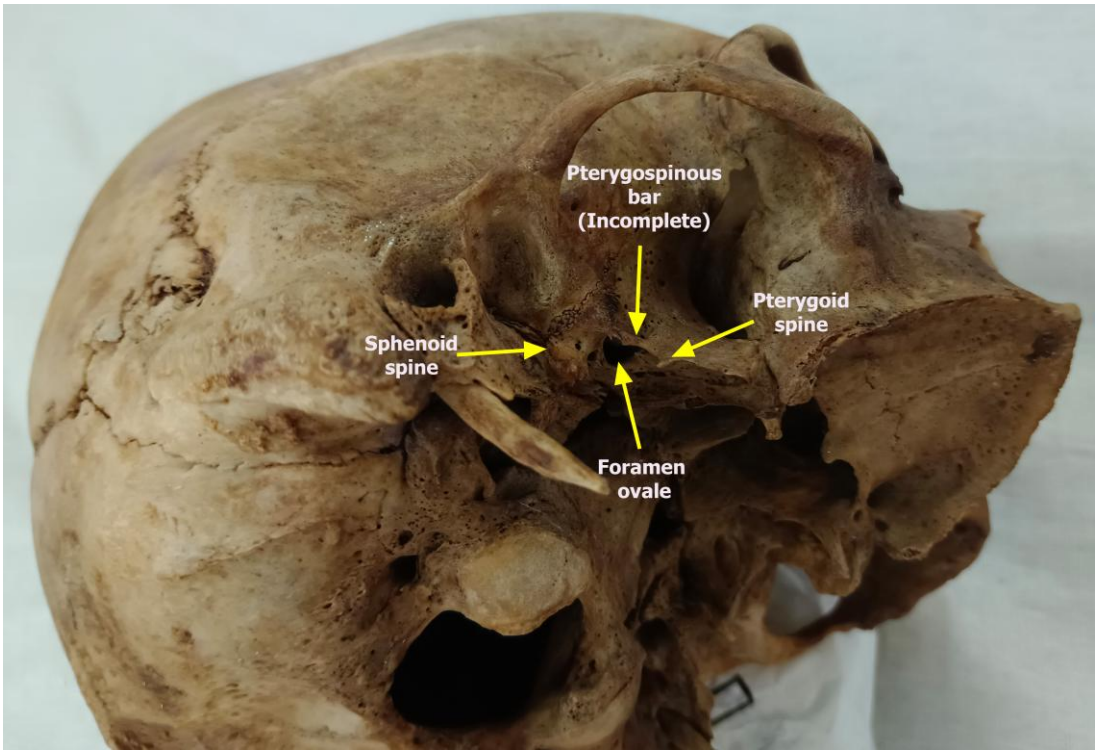

Figure 2. Incomplete pterygospinous bar on the right side. The bar is lateral to the foramen ovale

Table 1: Prevalence and Laterality of Pterygospinous Ossification (n = 50)

Type of Pterygospinous Bar	Right Side	Left Side	Bilateral
Complete	1	1	0
Incomplete	1	2	0
Total	2	3	0

The overall occurrence of pterygospinous ossification was 10%. Incomplete ossification (6%) was more prevalent than complete ossification (4%). All bars were unilateral.

Table 2: Relationship of pterygospinous bar with the foramen Ovale (n = 5)

Type of Bar	Medial to Foramen Ovale	Lateral to Foramen Ovale
Complete	0	2
Incomplete	0	3
Total	0	5

DISCUSSION

Associated with the sphenoid bone at the cranial base, there are multiple ligaments including the pterygospinous, interclinoid, carotico-clinoid and pterygoalar ligaments. Any of these ligaments may ossify and have clinical significance. The occurrence of pterygospinous ossification is widely variable in different populations as reported by various authors. A comparative synopsis of the previous studies and the present study is shown in Table 3.

Table 3: The prevalence of ossified pterygospinous ligament among various ethnic groups

Sr. No.	Previous studies	Year	Race	Subjects	*% Prevalence & No. of ossified PS ligaments*	
					Incomplete	**Complete**
1	Kapur [12]	2000	Bosnians, Herzegowinians	305	14.8 (45)	3.6 (11)
2	von Ludinghuasen [13]	2006	Japanese	100	11 (11)	6 (6)
3	Nayak [14]	2007	Indians	416	3.8 (16)	5.8 (24)

4	Das and Paul [15]	2007	Indians	50	2 (1)	0
5	Antonopoulou [16]	2008	Greeks	50	50 (25)	4 (2)
6	Tubbs [17]	2009	Americans	154	0.7 (1)	0.7 (1)
7	Suazo [18]	2010	Brazilians	312	13.1 (41)	1.6 (5)
8	Aggarwal [19]	2012	Indian	67	6.72 (9)	2.98 (4)
9	Verma [20]	2013	Indians	116	12.9 (15)	1.7 (2)
	Present study	2026	Indian	50	6 (3)	4 (2)

The present study revealed an overall prevalence of ossified pterygospinous bar at 10% in Indian skulls, consistent with findings of Nayak and Aggarwal, which reported rates of 9.61% and 9.7% in Indian populations, respectively. [14, 19] In the present study, complete ossification was observed in 4% and incomplete ossification in 6% of the skulls. The incomplete form was more prevalent than the complete form, consistent with the majority of previous research. Das and Paul documented a singular instance of incomplete ossification in a sample of 50 skulls, while Aggarwal et al. noted incomplete ossification in 9 out of 67 skulls. [15, 19] In each case of the present study, the bar was unilateral and situated laterally to the foramen ovale. While the pterygospinous bar is typically characterized in humans as situated inferior or medial to the foramen ovale, a lateral positioning has been recorded in the standard pithecoid configuration.[10] Consequently, the current finding can be considered an anatomical variant akin to the spatial configuration noted in some non-human primates; yet, this observation by itself cannot be construed as proof of an evolutionary connection. In the present study, the bony bridges were identified according to their attachment to the pterygoid and sphenoid spines, supporting their classification as pterygospinous bars despite their lateral position relative to the foramen ovale. The lateral position in the present specimens may be a natural anatomic variant of the three-dimensional configuration of the sphenoid and the course of the ossified pterygospinous ligament. A typical anatomical relationship is hence the often-reported medial or inferior relationship to the foramen ovale. Variations in orientation of the pterygoid process, location of the pterygoid and sphenoid spines and the direction of ligamentous ossification may vary the ultimate position of the bony bar relative to the foramen ovale. The present study does not necessarily imply misidentification of a pterygoalar bar, but could be an uncommon topographical variety of the pterygospinous bar.

Previous comparative studies have reported that the pterygospinous bar is well developed or complete in several non-human mammalian groups such as herbivores, carnivores and some non-human primates, whereas it is generally less developed or incompletely ossified in humans and anthropoid primates.[13] The pterygospinous bar has also been described as complete and situated lateral to the foramen ovale in the typical pithecoid condition.[10] Such observations have led previous investigators to consider the human pterygospinous bar a possible phylogenetic remnant. Thus, the present finding of ossification of the pterygospinous ligament in human dry skulls supports the view that it is a retained anatomical feature with a wider comparative distribution among mammals. However, the present study did not examine non-human mammalian specimens and so cannot independently test the evolutionary origin, ancestral state, or phylogenetic trajectory of pterygospinous ossification. The phylogenetic interpretation presented here therefore should be taken as a contextual interpretation, based on previously published comparative anatomical evidence. To directly test this notion dedicated comparison research incorporating properly classified mammalian taxa would be required.

These anatomical variances hold significance not only from embryological

and anatomical viewpoints but also in clinical applications because the variable position of an ossified pterygospinous ligament may alter its relationship with the foramen ovale and the mandibular nerve. The conventional anatomical descriptions should not be used as fixed positioning criteria to identify these structures during anatomical, radiological, or surgical procedures. Antonopoulou et al., stated that ossified pterygospinous bars can modify the course of the mandibular nerve and complicate operative procedures like inferior alveolar nerve block.[16] When performing the lateral sub-zygomatic approach to block the mandibular nerve, an ossified bar at the posterior margin of the lateral pterygoid plate may obstruct placement of the needle. Dental anesthesia relies on the lateral pterygoid plate, therefore any bony anomaly there may make analgesia difficult.[12] According to Peuker et al, ossified pterygospinous ligaments entrap the lingual nerve causing speech difficulty and lingual numbness and pain. When the pterygospinous ligament ossifies, main trunk of the mandibular nerve displaces laterally. Thus, the terminal branches - lingual and inferior alveolar nerves – must cross the extended lateral pterygoid plate. This anomalous pathway increases nerve compression between osseous and muscular components, causing neuralgic pain. An ossified ligament may prevent mandibular nerve block, which is used to treat mandibular fractures and mouth cancer, and local anesthetic for trigeminal neuralgia surgery. [21] In humans, the bony bridge may divide the lingual nerve into anterior and posterior sections. Medial to the pterygospinous bar, anterior fibers are more susceptible to compression between the tensor veli palatini and the bony bridge. [22]

The ligament's complete or incomplete ossification is situated near numerous key structures in the infratemporal area. This encompasses the mandibular nerve as it traverses the foramen ovale, its branches, the otic ganglion, middle meningeal vessels, tympanic nerve, and the medial and lateral pterygoid muscles. Compression of these structures against the bony bar may result in clinical symptoms like masticatory pain and could possibly exacerbate trigeminal neuralgia.[23]

Considering the phylogenetic context and clinical significance of pterygospinous bars and foramina, understanding their prevalence and morphology is crucial for surgeons, anesthesiologists, dentists, anatomists, and anthropologists.

CONCLUSION

The present study revealed that pterygospinous ossification was present in 10% of dry adult human skulls studied from Gujarat. Incomplete ossification occurred more frequently than complete, and all detected bony bars were unilateral and situated laterally to the foramen ovale. Despite these variations typically being asymptomatic, their proximity to the mandibular nerve and its branches renders them clinically significant. Recognition of these bony anatomical variations is thus crucial for anatomists, surgeons, dentists, and anaesthesiologists, especially as they may provide challenges during procedures like inferior alveolar nerve block and treatments for trigeminal neuralgia. Additional extensive research, both cadaveric and radiological, is necessary to determine the precise comprehension of the embryological foundation of pterygospinous ossification and its potential clinical consequences.

Declaration

Ethical Approval: Approval No. No. IEC/Approval /47 / 01/09/2023, Institutional Ethics Committee, GMERS Medical College & General Hospital, Himmatnagar.

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Conflict of Interest: The authors declare no conflict of interest.

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