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# Morphometric Study of Unusual Foramina of The Sphenoid Bone

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**Abstract**

**Background:** The Pterygospinous and the Pterygoalar foramina are rare anatomical structures on the skull's base near the sphenoid bone. These structures have clinical significance as landmarks in medical and surgical procedures. Understanding the anatomy and incidence of ossified ligaments associated with these foramina is crucial for neurosurgical, dental, and maxillofacial procedures. The present study was undertaken to assess the incidence, structural details and clinical importance of formation of unusual foramina of sphenoid bone in the skulls of Indian population.

**Methods**: The present observational study was conducted on 200 dry skulls and disconnected sphenoid bones. Direct cranioscopy and digital caliper measurements were used to assess the pterygospinous and pterygoalar foramina, ossification, and location of ligaments. The observed data were statistically analyzed using SPSS 22 software.

**Results**: Complete ossification of the pterygospinous foramen was observed bilaterally in 1% of bones, with incomplete ossification in 5.5% of bones. In the pterygoalar foramen, complete ossification was found in 2% of cases on the left and 1% on the right sides. Incomplete ossification was observed in 1% on the left side, 2.5% on the right side, and 1.5% bilaterally. The measurements of both foramina indicated that the Pterygospinous foramen had a larger diameter than the Pterygoalar foramen.

**Conclusion**: The incidence of ossified pterygospinous and pterygoalar ligaments and their foramina formation in the skulls of the Indian population is low. Understanding the prevalence and anatomy of these structures is crucial for medical professionals to diagnose and treat neurological and maxillofacial conditions.

**Keywords:** Pterygospinous foramen; Pterygoalar foramen; Sphenoid bone; Ossification; Anatomical landmark; Neurosurgical procedures; Maxillofacial surgeries.

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## Introduction

The study of human anatomy has always been of paramount importance in the medical field, with particular attention paid to the intricate structures of the head and neck region. The Pterygoid process of sphenoid bone hangs down from its body and greater wing in the infratemporal fossa.

Pterygoid process has a medial and a lateral pterygoid plate. Each lateral plate has anterior and posterior margins. Within this context, two important anatomical landmarks garnered significant attention. The Pterygospinous (Civinini) and the Pterygoalar (Crotaphitico-Buccinatorius) foramina are anatomical structures near the sphenoid bone. The sphenoid bone plays a vital role in the skull's structural integrity and in the cranial base's formation. The presence of the foramina in the sphenoid bone holds significant clinical importance, as they are essential landmarks in various medical and surgical procedures.[1] The Pterygospinous Foramen, named after the Italian anatomist Pietro Civinini, is an opening through which the middle meningeal artery passes.

This artery is responsible for supplying blood to the dura mater of the brain, and damage to it can result in serious complications such as epidural hematomas and intracranial hemorrhage. As such, knowledge of the location and anatomy of this foramen is crucial in neurosurgical procedures and the diagnosis and treatment of traumatic brain injuries. The Pterygospinous ligament is a band of connective tissue that extends from upper part of posterior border of lateral pterygoid plate and spine of sphenoid bone. In some cases, this ligament undergoes complete or incomplete ossification. When fully ossified, the resulting bony bridge is known as Civinini's bar, or the Pterygospinous bar. The ossified bar results in the formation of foramen Civinini or the pterygospinous foramen.[2,3]

The Pterygoalar (Crotaphitico-Buccinatorius) foramen is another unusual opening in the sphenoid bone, serving as the exit point for the deep temporal nerves. These nerves innervate the temporalis muscle, a key muscle involved in mastication and jaw movement.

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Understanding the location and anatomy of this foramen is essential in dental and maxillofacial surgeries and in treating temporomandibular joint disorders.[4] The pterygoalar ligament connects the undersurface of the greater wing of the sphenoid bone and the root of the lateral pterygoid plate. It can get ossified partially or entirely, leading to the formation of pterygoalar or porus crotophitico- buccinitorious. Both the pterygospinous and pterygoalar bars are secondary ossifications of intrinsic ligaments of the sphenoid bone. Their presence in children's skulls may suggest the possibility of genetic factors. These bony bridges are more common in Africans, meaning racial variations.[2,3,5] The bars are intricately associated with the and can potentially cause compression of the mandibular nerve and its branches, leading to entrapment neuropathy. The foramen ovale is close to pterygospinous and pterygoalar bars, and these bars may cause entrapment neuropathy of the mandibular nerve. These osseous bridges present a formidable challenge to surgeons attempting to access retro and para pharyngeal spaces or perform trigeminal ganglion block through the foramen Ovale.[6,7] Mastery of these complex anatomical structures is a critical prerequisite for medical professionals diagnosing and managing various disorders and pathologies impacting the head and neck region. A profound understanding of these landmarks is indispensable for any medical professional dealing with patients afflicted with neurological or maxillofacial conditions. In this context, the present study was undertaken to assess the incidence, structural details and clinical importance of formation of unusual foramina of sphenoid bone in the skulls of Indian population.

## Materials and Methods

### *Setting*

The prospective observational study was conducted in the postgraduate department of Anatomy Government Medical College Srinagar, Jammu and Kashmir, India, form June 2023 to August 2023.

### *Sampling*

A total of 200 bone specimens comprising dry skulls and disjointed sphenoid bones were meticulously chosen from the bone bank of the Anatomy department. The determination of a sample size consisting of 200 bone specimens was meticulously calculated, taking into account resource constraints and the pragmatic feasibility of conducting a thorough and exhaustive analysis. This sample size was driven by the imperative to provide robust insights while remaining within the boundaries of available resources.

### *Random Selection for unbiased Sampling*

To preempt selection bias, the specimens were chosen through a rigorous process of random selection. This methodological approach was meticulously adopted to ensure that every specimen had an equal opportunity of being included, safeguarding the impartiality of the selection process.

### *Inclusion Criteria*

1. Adult Human Dry Skulls: The study explicitly confined its inclusion criteria to exclusively encompass adult human dry skulls. This discerning criterion served to uphold the anatomical maturity necessary for the research objectives.
2. Unknown Age and Sex: Deliberately, specimens of unknown age and sex were favored for inclusion, eliminating the influence of these variables on the sample composition.
3. Well-Defined Skull Sutures: Rigorously adhering to stringent criteria, only specimens featuring well-defined skull sutures were selected. This requirement was deemed indispensable to ensure the precision of anatomical evaluations.

### *Exclusion Criteria*

Exclusion of damaged bones: As a measure to safeguard the integrity of the study, any skulls/bones that displayed significant damage or possessed attributes rendering the foramina unidentifiable were categorically excluded. This exclusion was deemed essential to maintain the quality and suitability of the specimens designated for analysis.

To minimize the risk of selection bias, a standardized protocol was meticulously implemented. The meticulous selection of 200 specimens was underpinned by a methodological commitment to represent the sphenoid bone population's diversity comprehensively. This protocol underscored the significance of random selection, particularly within predetermined categories, reinforcing the study's commitment to curating a representative sample. Moreover, the utilization of a digital Vernier's caliper, characterized by its high precision with a resolution of 0.1 mm, was instrumental in achieving consistent and accurate measurements. This strategic choice in measurement tools significantly contributed to the reduction of potential biases in the recorded measurements.

### *Methodology*

The specimens were assessed by direct observation by a single examiner (first author), occasionally, taking help of magnifying glass. The investigation focused on the pterygospinous foramen and pterygoalar foramen about the structural integrity of the region with a focus on the natural foramina of the sphenoid bone. Sex and age identification were not established in any of the specimens. The unusual foramina and the osseous bars were measured by a digital Vernier's caliper (Western Pro) with a resolution of 0.1 mm. Radinsky's formula was employed in calculating the area for each foramen.[8] The skull base was examined to determine the location of the pterygospinous and pterygoalar ligaments (right, left, or bilateral), the degree of ossification (complete or incomplete), the relationship of the bar to the foramen ovale (medial, lateral, or across), and the measurements of the osseous bridges (length and width) as well as the dimensions of the pterygospinous / pterygoalar foramina (vertical and horizontal diameter). This comprehensive approach provides valuable insights into the intricate details of these anatomical structures and their clinical implications, thereby aiding medical professionals in diagnosing and treating various neurological and maxillofacial conditions.

### *Statistical Methods*

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel 2016) and then exported to the data editor of SPSS Version 22.0 (SPSS Inc., Chicago, Illinois, USA) for statistical analysis. Continuous variables were expressed as Mean and standard deviation; categorical variables were summarized as percentages.

## Results

### *Pterygospinous foramen*

The incidence of complete and incomplete ossification of the Pterygospinous foramen in the left, right and bilateral sides is depicted in Table 1, Figure 1. Among the total of 200 bones included in the study, complete ossification was found in 1.0% (2 bones) on the left side, 1.0% (2 bones) on the right side, and 1.0% (2 bones) bilaterally. Regarding incomplete ossification, 5.5% (11 bones) displayed this condition on the left side, 5.5% (11 bones) on the right side, and 5.5% (11 bones) bilaterally. The majority of cases exhibited an absence of ossification in the pterygospinous foramen, with 93.5% (187 bones) showing no ossification on the left side, 93.5% (187 bones) on the right side, and 93.5% (187 bones) bilaterally. These findings suggest a low incidence of ossification of the pterygospinous foramen in the studied population.

**Table 1.** Incidence of complete/incomplete ossification of pterygospinous foramen.

| Pterygospinous foramen | Left | | Right | | Bilateral | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| **Complete** | 2 | 1.0 | 2 | 1.0 | 2 | 1.0 |
| **Incomplete** | 11 | 5.5 | 11 | 5.5 | 11 | 5.5 |
| **Absent** | 187 | 93.5 | 187 | 93.5 | 187 | 93.5 |
| **Total** | 200 | 100 | 200 | 100 | 200 | 100 |

### *Pterygoalar foramen*

Table 2 and Figure 2 shows the incidence of complete and incomplete ossification of the pterygoalar foramen, categorized by left, right, and bilateral sides. For the left side, complete ossification was observed in 4 cases, accounting for 2.0% of the total occurrences. Incomplete ossification was detected in 2 bones, making up 1.0% of the instances. The vast majority (97.0%) of bones on the left side showed the absence of ossification. On the right side, complete ossification was found in 2 bones, comprising 1.0% of the total. Incomplete ossification was seen in 5 bones, representing 2.5% of the occurrences. The remaining 96.5% of bones on the right side showed no ossification. For bilateral occurrences, complete ossification was not observed in any bone, and incomplete ossification was found in 3 bones (1.5%). Most (98.5%) of bilateral bones demonstrated an absence of ossification.

**Table 2.** Incidence of complete/incomplete ossification of pterygoalar foramen.

| Pterygospinous foramen | Left | | Right | | Bilateral | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| **Complete** | 4 | 2.0 | 2 | 1.0 | 0 | 0.0 |
| **Incomplete** | 2 | 1.0 | 5 | 2.5 | 3 | 1.5 |
| **Absent** | 194 | 97.0 | 193 | 96.5 | 197 | 98.5 |
| **Total** | 200 | 100 | 200 | 100 | 200 | 100 |

### *Measurements of the pterygospinous and pterygoalar foramina*

Measurements of the pterygospinous and pterygoalar foramen are shown in Table 3. The pterygospinous foramen's mean vertical diameter was 7.5 mm, with a standard deviation of 4.13 mm. The measurement range is from 6 mm to 10 mm. The mean horizontal diameter was 6.8 mm, with a standard deviation of 3.71 mm. The measurement range for the horizontal diameter is from 5 mm to 9 mm. For the pterygoalar foramen, the mean vertical diameter is 2.6 mm with a standard deviation of 2.14 mm. The measurement range for the vertical

**Table 3.** Measurement of pterygospinous and pterygoalar foramen.

| Statistical Measure | Pterygospinous foramen | | Pterygoalar foramen | |
|---|---|---|---|---|
| | Vertical Diameter (mm) | Horizontal diameter (mm) | Vertical diameter (mm) | Horizontal diameter (mm) |
| **Mean** | 7.5 | 6.8 | 2.6 | 3.5 |
| **SD** | 4.13 | 3.71 | 2.14 | 2.52 |
| **Range** | 6-10 | 5-9 | 1-5 | 2-6 |

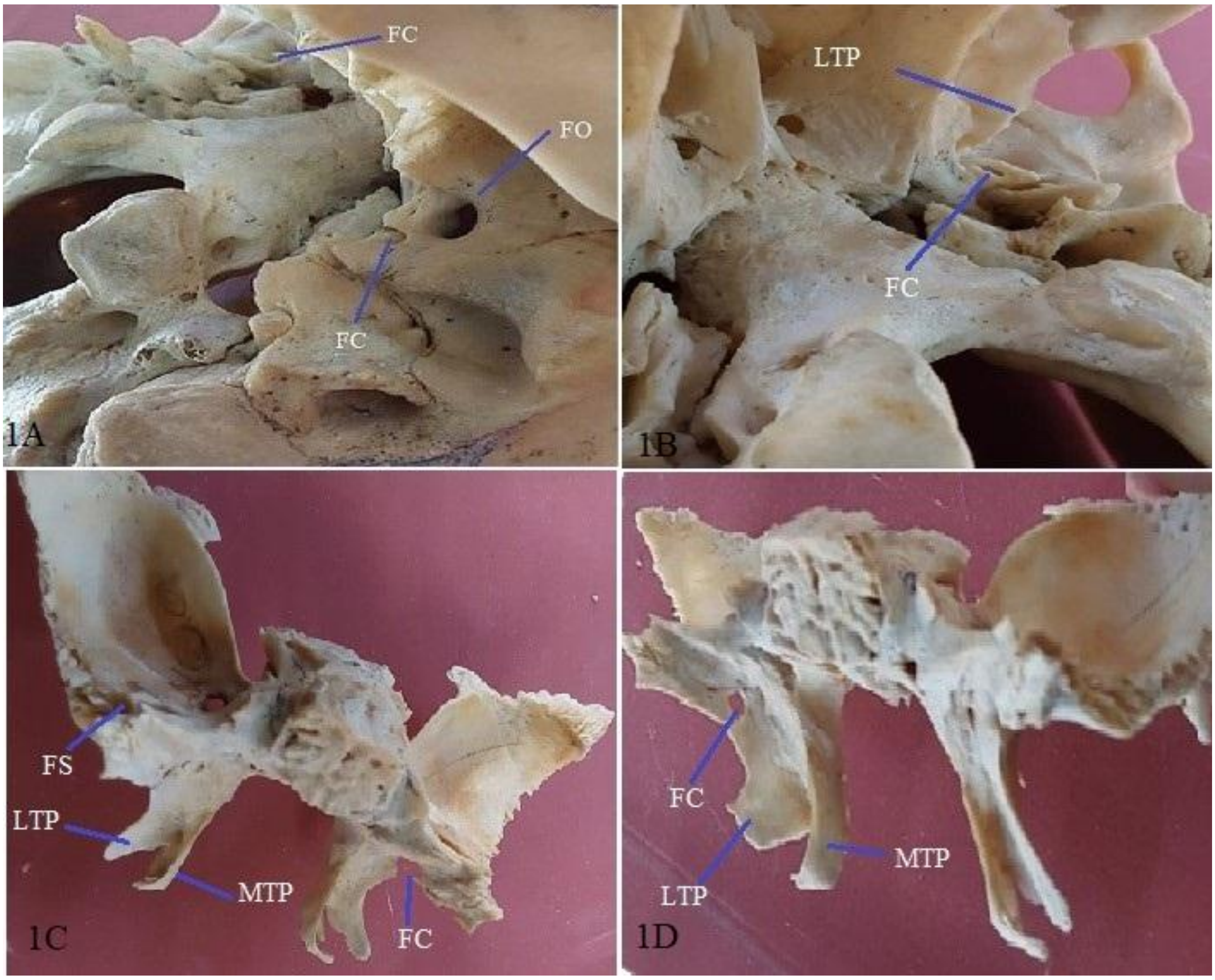


**Figure 1.** 1A, 1B and 1C showing incomplete ossification of Pterygospinous ligament forming incomplete foramen Civini and 1D showing complete ossification of Pterygospinous ligament forming complete foramen Civini (FC- foramen Civini, FO- foramen Ovale, FS- foramen Spinosum, MTP- medial pterygoid plate and LTP- lateral pterygoid plate).

diameter varies from 1 mm to 5 mm. The mean horizontal diameter is 3.5 mm, with a standard deviation of 2.52 mm. The measurement for the horizontal diameter ranges from 2 mm to 6 mm. These measurements provide insight into the dimensions of the pterygospinous and pterygoalar foramina, including mean size, variability, and extent within the study population.

## Discussion

The pterygoid hole and pterygoid foramen are important landmarks at the base of the skull, located on the posterior margin of the pterygoid process of the sphenoid bone. These foramina provide pathways for nerves and blood vessels, including the mandibular nerve, which plays an important role in innervating the muscles of the lower teeth and jaw. This study aimed to evaluate the incidence rate, clinical relevance and phylogenetic significance of pterygoid spinous ligament and pterygoid ligament ossification in the skull of an Indian population. In our study, the pterygospinous foramen showed incomplete ossification in 5.5% of bones bilaterally, with complete ossification observed in only 1% of bones bilaterally. On the left side, complete ossification was found in 1% of bones, incomplete ossification in 5.5% of bones, and the foramen was absent in 93.5% of bones. Similarly, on the right side, complete ossification was observed in 1% of bones, incomplete ossification in 5.5% of bones, and the foramen was absent in 93.5% of bones. In bilateral bones, complete ossification was present in 1% of bones, incomplete ossification was found in 5.5%, and the foramen was absent in 93.5% of bones. Based on the results of the current study, it was found that the complete ossification of the pterygospinous ligament was 3%, while incomplete ossification was observed in 16.5% of the specimens studied. Singh and Niranjan (2019)[9] reported in a study of 530 dry skulls that ossification was observed between complete and incomplete structures in 9.8% of specimens. Chouk (1947)[5] reported a 6.28% incidence of pterygospinous foramen formation in 1544 skulls, more frequent in white than black individuals.

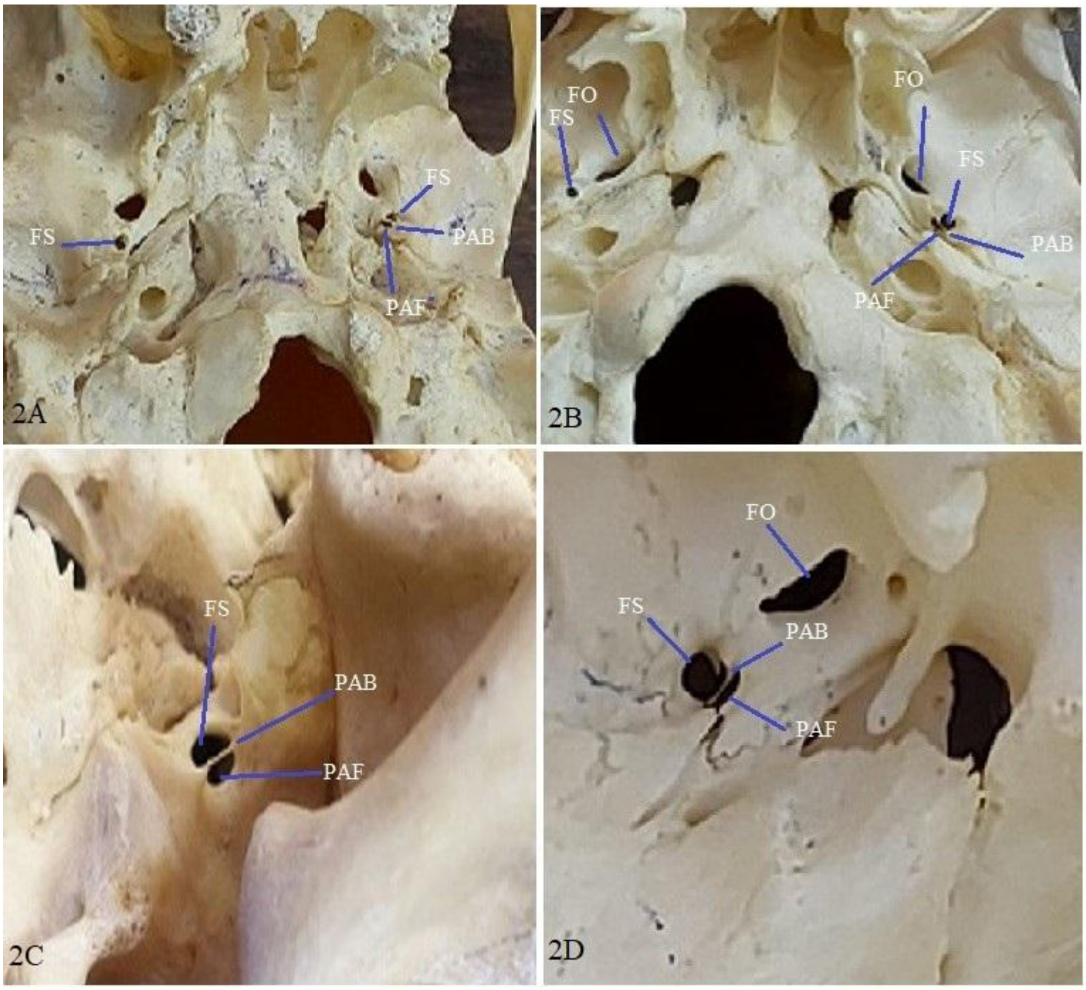


**Figure 2.** 1A, 1B and 1C showing ossification of pterygoalar bar forming pterygoalr foramen- external view of the skull. 1D showing ossification of pterygoalar bar forming pterygoalar foramen- inside view of the skull. (FS- foramen spinoum, FO-foramen Ovale, PAB- pterygoalar bar, PAF- pterygoalar foramen).

Kamath and Vasant (2014)[10] noted 17 skulls (17%) with incomplete (16) and incomplete structures (1). Goyal and Jain (2016) [1] reported 17.33% complete and incomplete structures out of 75 specimens. Jansirani et al. (2012)[11] reported complete ossification of the pterygospinous ligament in only two skulls (0.98%) and incomplete ossification in 22 skulls (10.78%) out of 204 skulls. Yadav et al. (2014)[12] reported an incidence of 4% for complete formation of the pterygospinous foramen. Iwanaga et al. (2009)[4] reported that only two of 154 skulls had a pterygospinous foramen, one with complete formation and the other with incomplete formation (1.3%). Henry et al. (2020)[13] conducted a metanalytical study involving 35 studies (14.047 specimens) and reported a higher prevalence of incomplete formation of the pterygospinous foramen (11.6%) compared to complete formation (4.4%). While the incidence of complete and incomplete ossification of the pterygoid foramen at three different locations:[5] left, right, and bilateral, was assessed, we found complete ossification in 4 cases, constituting 2.0% of the entire observations. Conversely, incomplete ossification was discerned in two bones, amounting to 1.0% of the instances. The overwhelming majority of cases on the left side (97.0%) displayed the non-existence of ossification. Regarding the right side, complete ossification manifested in two bones, encompassing a mere 1.0% of the aggregate. Incomplete ossification was evident in 5 bones, representing 2.5% of the occurrences. The remaining 96.5% of bones on the right side showed no ossification. Complete ossification was absent in bilateral occurrences, while incomplete ossification was noted in three bones, accounting for 1.5% of the overall instances. Most bilateral bones (98.5%) demonstrated the absence of ossification. Other studies described the presence and variations of the pterygoalar ligament in different populations of human skulls. Ryu et al. (2016).[14]found 2.8% complete pterygoalar ligament ossifications in 2.8% and 5.6% incomplete ossification in dry skulls of adult Koreans. Natsis et al. (2014)[15] reported the presence of pterygoalar ligament in 31.7%, but only

4.1% of skulls had complete foramen and 2.7% unilaterally, and 2.7% bilaterally. Jansirani et al. (2012)[11] found complete ossification in the pterygoalar ligament in 2.45% and incomplete form in 3.92%. Skrzat et al. (2005)[16] analyzed 70 dry human skulls and noted the presence of a pterygoalar foramen in only five skulls, all unilateral and located crossing the medial, lateral, and oval foramen. Kamath and Vasantha (2014)[10] reported complete formation by ossification of the pterygoalar ligament in only one skull, and most incomplete ossification occurred on the left side in 51.72% of cases.

Singh and Niranjan (2019)[9] noted that in lemurs, the position of the ossified ligament is medial to the foramen ovale, whereas, in anthropoids, it is lateral to the foramen ovale. Iwanaga et al. (2020)[4] reported the occurrence of pterygoalar ligaments in 16 of 30 specimens (53%), with 11 cases being type I ligaments and five ligaments classified by the authors as type II. One of the 45 specimens evaluated in the study (2.2%) was found to have a complete pterygoalar foramen bilaterally. The findings were comparable to those of previous studies conducted on Indian, Brazilian, and Greek populations. However, the incidence of ossification was higher among the African people. [11]

Multiple classifications exist when analyzing the configurations of the foramen, including the conformity, simultaneity between pterygospinous and pterygoalar, and the extent of calcification. For example, Kamath and Vasantha (2014)[10] conducted a survey in which the authors classified the foramen into three types based on these parameters. Similarly, Suazo et al. (2010)[17] classified the foramen into four types based on criteria of ossification extension (complete or incomplete) without conducting morphometric analysis, which was also adopted by Ryu et al. (2016).[14]

The findings of the present study showed that the mean vertical diameter of the pterygospinous foramen was 7.5 mm with a standard deviation of 4.13 mm, while the mean horizontal diameter was 6.8 mm with a standard deviation of 3.71 mm. Jansirani et al. (2012)[11], found these dimensions to be 10 mm in length and 2.5 mm in width, respectively. In another study by Nayak et al. (2007)[18], the average dimensions of the pterygospinus bar were 6.22 mm in length and 3.35 mm in width, which is consistent with our study. On the other hand, the mean vertical diameter for the pterygoalar foramen was 2.6mm with a SD of 2.14mm, while the mean horizontal diameter was 3.5mm with a SD of 2.52 mm. In the present study, the range for the pterygospinous foramen vertical diameter was 6-10mm, while the range for the horizontal diameter was 5-9 mm. The range for the pterygoalar foramen vertical diameter was 1-5mm, while the range for the horizontal diameter was 2-6mm. Suazo et al. (2010)[17], reported that the diameter of pterygoalar foramen (3.79 to 5.2 mm) was comparatively less than that of pterygospinous foramen (7.36-10.62 mm). Similarly, Jansirani et al. (2012)[11], found that the mean size of the pterygoalar foramen (2.7x3.2 mm) was smaller than that of the pterygospinous foramen (7x7.5 mm), which is consistent with our study. Lepp et al. (1968)[6] proposed that the pterygoalar bar is closer to the base of the skull, while the pterygospinous bar is located farther from the base of the skull. This anatomical feature accounts for the smaller size of the pterygoal foramen compared to the pterygospinous foramen. It has been explained that the orientation of the pterygoalar bar in relation to the foramen ovale is varied, being located either medially or laterally, or completely crossing it. Because of its medial placement to the foramen ovale and proximity to the skull base, compression of the mandibular nerve branches by the pterygoalar bar may potentially be more prevalent. . These measurements provide valuable information for medical professionals who need to diagnose and treat disorders and diseases affecting the head and neck region. Wood Jones, (1931)[19] showed 8% of 100 Hawaiian skulls have unilateral completion of the pterygospinous bar, which was medial to the foramen ovale and not bilateral. Comparatively, New World monkeys, rodents, and platyrrhines show the absence of foramen Civinini. Pterygospinous bar represents a phylogenetic fossil of humans.[20]

As the pterygospinous bar is more medially oriented, it does not compromise the foramen ovale and has no clinical significance. Only the pterygoalar bar interferes with the injection of the mandibular nerve.[21] In contrast, the literature has proven that the pterygospinous bar is clinically significant.[22] The possibility of entrapment or compression of the lingual nerve from the ossified pterygospinous ligament or between the ossified ligament and the medial pterygoid muscle has been reported.[23] The course of the branches of the mandibular nerve and maxillary artery may change during development because the development of the ligament or band is hindered, and the branches of the mandibular nerve are also compressed, or it is extremely accidental that these structures are difficult to approach. The presence of an ossified pterygospinous ligament can make thermocoagulation and anesthesia difficult for trigeminal neuralgia, and it can create surgical difficulty in a lateral trans zygomatic infratemporal fossa approach to the para and retropharyngeal spaces.[24]. Entrapment and compression of the lingual nerve may occur due to partial or complete ossification of the pterygospinous ligament. The pterygospinous bar ridge separates the trunk of the lingual nerve into anterior and posterior branches. The anterior fibers may be compressed due to their course between the tensor valley palatini muscle and the bony ridge or due to the large lateral pterygoid plate.[2,23]

The existence of an osseous bar between the lateral pterygoid plate and the sphenoid vertebra is considered a human phylogenetic remnant. Wide pterygospinous bars are recorded in all carnivores, and Old-World monkeys, and small pterygospinous bars are recorded in rodents, but never in New World monkeys. Thus, in humans, this pterygospinous bar represents a phylogenetic remnant.[7] In lemurs, the bar lies medial to foramen ovale, but in the case of pithecoids the pterygospinous bar lies lateral to foramen ovale. The pterygospinous and pterygoalar bars may be incomplete in humans and anthropoids; and if the bars are in varying degrees of union may result in porous crotaphiticobuccinatorius and Civinini foramina.[7,19] While managing trigeminal neuralgia, it is imperative to consider the possibility of ossified bars as a potential etiology and thoroughly evaluate them. This comprehensive assessment will facilitate early surgical decompression, resolving the root cause of nerve entrapment. Additionally, if these bars are identified prior to trigeminal ganglion block, an alternative inframandibular approach may be more appropriate to achieve a better outcome. In conclusion, knowledge about pterygospinous and pterygoalar ligament ossification is important not only for anatomists and anthropologists, but also for doctors, anesthesiologists, dentists, radiologists, as well as oral and maxillofacial surgeons for optimal patient care.

## Conclusion

The present study demonstrated a low incidence of ossification of the pterygospinous foramen in all three locations, with complete ossification observed in only a few cases. The overall incidence of complete ossification of the pterygospinous ligament was found to be 0.98%, while incomplete ossification was observed in 10.78% of the specimens. In the case of the pterygoalar foramen, complete ossification was observed in only 1.5%, and incomplete ossification was found in 3.73% of the specimens. The measurements of both the foramina indicated that the pterygospinous foramen had a larger diameter than the pterygoalar foramen.

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### Ethical consideration

Our article titled, "Unusual Foramina of the dry Sphenoid bone- a Morphometric study" has been prepared taking into consideration all issues in ethics in publication. The project was cleared by Institutional Review Board vide communication: IRB/GMC/ANAT 69, dated: 13-05-2023.

### Competing Interests

The authors declare no conflict of interest.

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