Original Article

Anatomical Study of Pterygoalar and Pterygospinous Bars/Foramina in West Anatolian Skulls

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Abstract

Introduction: Pterygoalar bar (PTAB) is a bony bridge formed by the incomplete or complete ossification of the pterygoalar ligament extending between the lateral pterygoid lamina (LPL) and the greater wing of the sphenoid bone. Complete ossification of the pterygoalar ligament results in the formation of the so-called "pterygoalar foramen" (PTAF) or Hyrtl's foramen. On the other hand, pterygospinous bar (PTSB) is another bony bridge resulting from incomplete or complete ossification of the pterygospinous ligament, which extends from the pterygospinous process of the LPL to the sphenoidal spine. Complete ossification of this ligament forms the pterygospinous foramen (PTSF) or the Civinini's foramen. This study was undertaken to examine detailed anatomy and incidence of PTAB, PTSB, and the corresponding foramina, as well as to establish their relationship with foramen ovale (FO). **Materials and Methods:** A total of 152 dry adult human skulls (304 sides) obtained from the collection of the Anatomy Department of Dokuz Eylül University were examined in terms of the presence/absence of PTAB/PTSB, their incidence and side, degree of ossification (complete/incomplete), and their relationship with FO. The distance between the spinous processes was measured in cases with incomplete ossification of PTAB/PTSB, whereas a digital caliper with 0.01 mm sensitivity (Mitutoyo, Japan) was used to measure horizontal and vertical diameters of the foramina in cases with complete ossification (i.e., when PTAF and PTSF were present). SPSS 22.0 statistical software was used for statistical analysis with Student's *t*-test and Pearson's correlation analysis. The level of significance was set at $P < 0.05$. **Results:** Of the 152 skulls, 11 (7.23%) harbored PTAF and 2 harbored PTSF (1.3%). An incomplete PTAB or incomplete PTSB was present in 110/304 (33.4%) and 21/304 (6.9%) of the sides examined, respectively. PTAB was located medial, lateral, inferior, inferolateral, and inferomedial to FO in 15 (4.93), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) of the sides. The distance between PTAB and FO was 7.43 ± 2.58 mm on the right and 7.51 ± 2.50 mm on the left. The distance between two PTABs was 10.43 ± 3.65 mm on the right and 10.29 ± 3.30 mm on the left. The vertical diameter of PTAF was 3.80 ± 2.08 mm, and the horizontal diameter was 4.96 ± 2.24. In the presence of a foramen, the mean thickness of PTAB was 2.27 ± 0.74 mm, the mean width was 3.45 ± 3.40 mm, and the mean length was 6.54 ± 3.64 mm. No significant differences were identified between right- and left-sided measurements ($P > 0.05$). **Discussion and Conclusion:** Close adjacency of PTAB/PTSB to FO as well as their ability to form foramina may hamper the procedures requiring placement of transcutaneous needles into FO or may present anatomical challenges in surgery involving the base of the cranium. Owing to the possibility of neural compression, they may also have clinical significance for craniofacial neurosurgeons, anesthesiologists, radiologists, and dental surgeons. Our results may provide some anatomical insights for planning infratemporal fossa surgery.

Keywords: *Foramen ovale, pterygoalar bar, pterygoalar foramen, pterygospinous bar, pterygospinous foramen, trigeminal neuralgia*

Article Info

Received: 28 October 2022
Revised: 17 August 2023
Accepted: 26 November 2023
Available online: 30 December 2023

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Access this article online

Website: https://journals.lww.com/joai
DOI: 10.4103/jasi.jasi_156_22
Quick Response Code:

Introduction

In the upper part of the infratemporal area, there are two ligaments originating from the interpterygoid aponeuroses that extend from the lateral pterygoid lamina (LPL) of the pterygoid process to the infratemporal surface of the sphenoid bone. The pterygoalar ligament (Hyrtl's ligament) is formed by the upper margin of the lateral interpterygoid aponeurosis, which extends from the root of LPL to the infratemporal surface of the greater wing of the sphenoid bone anterolateral to the foramen spinosum. This ligament courses lateral to the foramen ovale (FO) and anterolateral to the sphenoidal spine.[1] Pterygospinous ligament (Civinini's ligament), which represents a thickening of the fascia between lateral and medial pterygoid muscles, extends

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How to cite this article: Aksu F, Karabekir S. Anatomical study of pterygoalar and pterygospinous bars/foramina in west Anatolian skulls. J Anat Soc India 2023;72:334-42.

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from the pterygospinous process of LPL to the sphenoidal spine. Therefore, as compared to pterygoalar ligament, pterygospinous ligament follows a course that is more medial, is further away from the base of the skull, attaches more posteriorly, and generally extends by crossing the lumen of FO.[2-4]

Partial or complete ossification of pterygoalar ligament leads to the formation of an anatomical structure known as pterygoalar bar (PTAB), which is closely located to FO.[4-9] Complete ossification of pterygoalar ligament results in the formation of pterygoalar foramen (PTAF), also known as Hyrtl's foramen, through which motor branches of the mandibular nerve (buccinator, lateral pterygoid, and temporalis muscle) as well as the auriculotemporal nerve, veins of pterygoid venous plexus, and certain arterioles[7,10-14] are reported to pass. The presence of PTAB may lead to certain neurological disorders such as difficulty in mastication, neuralgia, loss of taste sensation, paresthesia in the face or tongue, or reduced salivation from the parotid glands, as a result of compression effect on deep temporal, lateral pterygoid, buccal, auriculotemporal, and lingual branches of the mandibular nerve as well as on chorda tympani.[14-17] Furthermore, it has considerable clinical significance, since it may lead to nerve compression or trapped nerve during percutaneous anesthetic procedures for trigeminal neuralgia, in addition to the potential risk for interfering with needle access to FO.[3,6,18-20] Thus, a sound anatomical knowledge of these bony bridges and their prevalence is important for surgeons, neurologists, and anesthesiologists.[3,5,7-9,11,18]

Pterygospinous bar (PTSB) is a bony bridge formed by the incomplete or complete ossification of the pterygospinous ligament. Total ossification of this ligament creates the pterygospinous foramen (PTSF), or the foramen of Civinini, that conveys branches of the mandibular nerve and that may result in a variety of anatomical variations.[4,7,9,11] The branches of the medial meningeal artery and nerve supplying the medial pterygoid muscle as well as the masticatory branches of the mandibular nerve pass through PTSF.[21] An ossified pterygospinous ligament may cause paresthesia and pain in the presulcal areas of the tongue, base of the oral cavity, and gingival surfaces, impaired speech, anesthetic effect on the mucous glands of the tongue, as well as a loss of taste sense in the anterior two-thirds of the tongue due to compression of the adjacent chorda tympani.[3,11] The presence of PTSB may complicate surgery involving the lateral skull base as well as the parapharyngeal and retropharyngeal spaces approached through the infratemporal fossa.[11,13-15] Complete ossification of PTSB may also hamper the access of percutaneous needles to the trigeminal ganglion inserted through FO for mandibular nerve block and may complicate transzygomatic surgery.[3,5,8,10,11,22]

Ossification of the pterygospinous and pterygoalar ligaments and the resultant nerve compression may also manifest itself through symptoms such as mandibular neuralgia, nerve palsy, and headache, numbness, or syncope. While these ligaments are in close contact with important anatomical structures such as the mandibular nerve and its branches, otic ganglion median meningeal artery and vein, tympanic nerve, and medial and lateral pterygoid muscles, they occupy a deep and high position in the infratemporal fossa.[7]

This study was undertaken to examine the presence, incidence, and morphology of the ossified ligaments, i.e., PTAB and PTSB and the resultant PTAF and PTSF, as well as to evaluate their topographic relationship with FO.

Materials and Methods

A total of 152 adult dry skull samples of unknown sex and age from Western Anatolia were obtained from the Anatomy Department, Medical Faculty of Dokuz Eylül University. Ethical approval was not obtained for this study as it did not require participation of any live subjects instead only bony material was used. Skulls with evidence of significant trauma or pathology were excluded. The presence and incidence of PTAB/PTSB and PTAF/PTSF were examined in 304 sides [Figures 1-5].

Based on observations on both bones between which the ligaments extend, PTAB and PTSB were defined as "incomplete" when trabeculae and processes failed to unite, whereas they were designated as "complete" when union was present leading to formation of a foramen.[7,15] In case of incomplete ossification of PTAB/PTSB, the distance was measured using a digital sliding caliper (Mitutoyo, Japan) with a sensitivity of 0.01 in vertical and horizontal diameters for samples harboring PTAF/PTSF with two bony processes. In the presence of a complete bony bar, the width, length, and thickness of the bar obliterating the foramen were measured [Figures 1-5]. The relationship between these structures and FO was explored. In addition, the shortest distance from PTAB to FO was recorded.

Statistical analysis was performed using SPSS ver. 22.0 (SPSS Inc., Chicago, IL, USA) statistical software pack with Student's *t*-test and Pearson's correlation test. The level of significance was set at $P < 0.05$.

Results

Among 152 dry skulls overall, PTAF was present in 11 (3.6%; left sided in six and right sided in five) and PTSF was present in 2 (0.6%; one in the right and one in the left). Of these, concurrent PTAF and PTSF on both right and left sides were present in only one (0.3%). Among 304 sides, an incomplete PTAB was present in 110 (33.4%), and an incomplete PTSB was present in 21 (6.9%) [Figures 1-5].

PTAB's location was medial, lateral, inferior, inferolateral, and inferomedial to FO in 15 (4.93%), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) cases, respectively. The PTAB-FO distance was 7.43 ± 2.58 mm on the right

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and 7.51 ± 2.50 mm on the left; the distance between two incomplete PTABs was 10.43 ± 3.65 mm on the right and 10.29 ± 3.30 mm on the left; the distance between two incomplete PTSBs was 8.70 ± 3.15 mm on the right and 8.70 ± 3.52 mm on the left [Table 1]. The mean vertical and horizontal diameters of PTAF were 3.80 ± 2.08 mm and 4.96 ± 2.24 mm, respectively. In the presence of complete PTAB, the mean thickness, width, and length of the bar were 2.27 ± 0.74 mm, 3.45 ± 3.40 mm, and 6.54 ± 3.64 mm, respectively. The vertical and horizontal diameters of PTSFs were 3.20 ± 0.69 and 3.70 ± 0.23 mm, respectively [Table 2].

Discussion

The terminology used for the ossified structures under the sphenoid bone that are adjacent to FO is far from being consistent. PTAB and PTAF have been rarely defined in the anatomic literature, and although major anatomy textbooks do not routinely refer to these structures, they are relatively common.[6,9] Furthermore, pterygospinous and pterygoalar ligaments exhibit a significant degree of variability in terms of complete or incomplete ossification. As such, the published literature regarding the incidence and morphometric features of PTAB and PTSB lacks consensus and provides variable data.[11] Furthermore, mechanisms underlying the formation and development of these structures are poorly understood. Genetic and evolutionary factors have been proposed to be involved in the occurrence of these bony structures, due to the presence of significant differences between ethnic groups in humans.[6] Although the occurrence of PTAB has been regarded as a natural secondary process, studies in child skulls showing the presence of ossified PTAB suggest that this anomaly may represent a genetic variation.[12] Even more interesting is the fact that the widespread presence of PTAB has been reported in skulls from herbivores, rodents, and adult monkeys, and some authors have even claimed that PTAB may be an atavistic structure.[23,24] Some studies showed a higher prevalence of PTAB among the elderly.[18]

Clinical significance of pterygoalar bar/pterygospinous bar

The presence of PTAB has two major clinical consequences: the potential to produce neurological symptoms and to act as a mechanical barrier for needle entry when approaching FO.[25] Until now, no prospective clinical studies have evaluated symptoms associated with the presence of PTAB. Published data on clinically significant PTAB are limited to case reports or case series, hence the lack of accurate data on the incidence of symptomatic patients with PTAB.[6] Irrespective of gender, as opposed to more common presence of PTAF on the left, PTSFs are generally right sided.[13] PTAF has been considered to have more clinical significance based on higher incidence, lower surface area, proximity to FO, more frequent occurrence of superposition, and more lateral position as compared to PTSF.[13] During percutaneous mandibular or trigeminal nerve block, smaller PTAF surface and thicker PTAB closing the foramen increase the likelihood of blood vessel and nerve compression, and superior or lateral position relative to FO renders access to FO difficult or even impossible, causing significant clinical challenges.[13]

According to some researchers, complete ossification of pterygoalar ligament may be more dangerous than complete ossification of pterygospinous ligament, since the former

Table 1: Distance between processes or tubercles in incomplete pterygoalar bar and pterygospinous bar for both sides

	Side	Minimum	Maximum	Median	Mean	SD	*P*
PTAB-FO distance (mm)	Right	2.6	18.6	7.25	7.43	2.58	0.81
	Left	2.6	16.4	7.25	7.51	2.50	
Distance between two incomplete PTABs	Right	2.6	19.9	10.5	10.43	3.65	0.73
	Left	2.7	19.5	9.9	10.29	3.30	
Distance between two incomplete PTSBs	Right	4.0	12.65	9.2	8.70	3.15	1.0
	Left	4.4	17.6	8.55	8.70	3.52	

Diameters of PTAF and PTSF and the dimensions of complete PTAB. PTAB: Pterygoalar bar, PTSB: Pterygospinous bar, FO: Foramen ovale, SD: Standard deviation

Table 2: Diameters of pterygoalar foramen and pterygospinous foramen

	Measurement	Minimum	Maximum	Median	Mean	SD	*P*
PTAF diameter (mm)	Vertical	2.3	9.5	3.1	3.80	2.08	0.22
	Horizontal	2.8	10.7	4.5	4.96	2.24	
Complete PTAB (mm)	Width	1.4	13	2.4	3.45	3.40	0.06
	Length	3.1	16	5.7	6.54	3.64	
	Thickness	0.9	3.2	2.5	2.27	0.74	
PTSF diameter (mm)	Vertical	2.6	3.8	3.2	3.20	0.69	0.21
	Horizontal	3.5	3.9	4.5	3.70	0.23	

Measured values in the presence of complete PTAB. PTAF: Pterygoalar foramen, PTSF: Pterygospinous foramen, PTAB: Pterygoalar bar, SD: Standard deviation

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may totally obstruct FO during thermocoagulation of trigeminal ganglion or mandibular nerve performed to treat trigeminal neuralgia, and these ossified ligaments may lead to inadequate anesthesia as a result of difficulties associated with the advancement of the needle through FO.[3,4,8,20,26]

Singh[20] in his anatomical study of 730 skull bases proposed a new and detailed classification to account for varying degrees of ossification of PTAB/PTSB. Literature search of that researcher showed a highly variable incidence of PTAF and PTSF reported in different populations, ranging between 1% and 31.2% and between 1.3% and 62.4%, respectively. Thus, morphological and topographical clarifications of these structures carry much significance.[20]

Pterygoalar bar/pterygoalar foramen prevalence and location

PTAB prevalence is considerably variable. In Chouke's study[23] involving 1544 dry skulls from America, complete PTAB was present in 10.3%, whereas in another study by the same author involving 2745 dry skulls, the prevalence was 5.9%. In Kapur *et al*.'s study,[13] incomplete ossification of the pterygoalar ligament was found in 20% of 100 dry skulls. In Pękala *et al*.'s meta-analysis,[6] the general prevalence of complete and incomplete PTAB was found to be 4.4% and 8.4%, respectively, with PTAB being more commonly observed unilaterally on the left. According to these authors, incomplete or complete PTAB prevalence was lowest among European populations. In a geographical subgroup analysis of that study, Asian populations were found to have the highest prevalence of PTAB (7.0%), followed by South (5.0%) and North (5.0%) America. A complete PTAB was least common in Europe (2.6%). In the current study of dry skulls from Western Anatolia, the PTAB occurrence rate was 3.6%. The reported prevalence of ossified PTAB exhibits significant variability between 1.3% and 62.4%.[4,14] According to Chouke,[23] the prevalence of Hyrtl's foramen was almost twice higher in Africans than in Caucasians (12.88% vs. 7.04%). While Kapur *et al*.[21] reported complete and incomplete PTAB in 5.9% and 14.4% of the skulls examined, respectively, the corresponding values reported by Peker *et al*.[15] in an Anatolian population were 9.7% and 10.2%. On the other hand, lower frequencies were reported in a Turkish population by Pinar *et al*.[27] and in an American population by Tubbs *et al*.;[14] the frequencies for complete and incomplete PTAB in these two studies were 1.1% and 0.7% and 4.98% and 0.7%, respectively. Interestingly, while Rosa *et al*.[4] observed the highest incidence of PTAB in the literature (12.9% for complete and 49.9% for incomplete ossification), Suazo *et al*.[28] reported much lower prevalence, again in a Brazilian sample (3.8% and 22.4%, respectively). Shaw[17] proposed that PTAB was present in approximately 1 out of 100 adults. A complete unilateral PTAB was present in approximately 5% of skulls from an Anatolian population, whereas bilateral PTAB was significantly less common (1%).[9] A similar incidence was reported for PTAF by Kapur *et al*.[21] According to Rossi *et al*.,[7] complete and incomplete ossification of the pterygoalar ligament was present in 2.73% and 0.54% of the human skulls, respectively. In contrast with these reports, Skrzat *et al*.[9] in a Polish population and Chakravarthi and Bab,[29] in an Indian population, observed higher frequencies of complete PTAB (7.1% and 19.7%, respectively) as compared to incomplete PTAB (1.4% and 8.5%, respectively). In a recent meta-analysis of dried human skulls, 4.4% of the samples harbored a completely ossified PTAB, as compared to 8.4% for incompletely ossified PTAB.[3] Ossified PTAB was present in 8.4% of the samples (2.8% complete and 5.6% incomplete) in the study by Ryu *et al*.[8] In an Indian sample of dry skulls, Harikrishnan[11] observed the presence of PTAB in 11% of the cases. In 1951, Chouke and Hodes[30] determined the presence of PTAB in a total of 1234 samples (bilateral 0.89%). Lepp and Sandner[26] reported that PTAB was present in approximately 8%–10% of the population, and that pterygoalar ligament was more commonly ossified than pterygospinous ligament. In Rosa *et al*.'s study,[4] PTAB was found in 62.35% of the radiographic images examined (49.44% incomplete and 12.91% complete ossification). The reported rates of incomplete and complete PTAB by Antonopoulou *et al*.[25] were 7% and 1%, respectively. In a cadaveric study of 15 samples by Iwanaga *et al*.,[31] 27 of the 30 sides examined had at least one pterygoalar ligament/bar or pterygospinous ligament/bar.

Complete pterygoalar foramen

This was observed in 14.7% of a Croatian population by Kapur *et al*.,[21] in 0.65% of an American population by Tubbs *et al*.,[14] and in 0.65%, 19.7%, and 0.3% of three separate Indian populations by Chakravarthi and Babu,[29] Kavitha Kamath and Vasantha,[5] and Singh,[20] respectively.

Incomplete pterygoalar foramen

This was reported in 49.4% of a Brazilian population by Rosa *et al*.[4] and in 29%, 3.92%, and 3.3% of three different Indian populations by Kavitha Kamath and Vasantha,[5] De Villiers,[32] and Singh.[20]

Kapur *et al*.[13] determined the presence of PTAF in 15% of 100 human skulls, with left-sided dominance of this structure; again, complete ossification, i.e., PTAB, was significantly more common on the left (12%) than on the right (3%).

Natsis *et al*.[18] found that 31.7% of the 145 dry skull samples from a Greek population harbored PTAB, with 4.1% of these being completely ossified (i.e., foramen) and 27.6% being incompletely ossified. Skrzat *et al*.[9] found the presence of PTAB and foramen in 5 of the 70 skulls examined.

The most common type of PTAB is unilateral incomplete type.[6] In most of the previous studies, PTAB was more commonly reported on the left.[5,14,17,23,33] De Villiers,[32]

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however, found more common presence of PTAB in an African sample of dry skulls. In Natsis *et al*.'s study,[18] no side dominance was observed. In our study, there was only a very small difference in the number of PTAB on the right and left sides of the skulls (one more PTAB on the right), consistent with Natsis *et al*.'s[18] observations.

Pterygoalar bar morphometry: The distance between two incomplete pterygoalar bars

The average distance between two incomplete PTABs reported by Natsis *et al*.[18] was 7.49 ± 2.76 mm. In our study, the corresponding values on the right and left were 10.43 ± 3.65 mm and 10.29 ± 3.30 mm, respectively. These differences may reflect geographical and ethnic differences.

Complete pterygoalar bar morphometry

The mean length of PTAB reported by Skrzat *et al*.[9] and Pękala *et al*.[6] was 4–8 mm and 6.27 mm, respectively. The mean PTAB length in our study, i.e., 6.54 ± 3.64 mm, was consistent with these previous reports. However, in contrast with these studies, PTAB width and thickness were also measured for the first time in our study which were found to be 2.27 ± 0.74 mm and 3.45 ± 3.40 mm, respectively.

Pterygoalar foramen morphometry

Published literature provides no information regarding the effect of the dimensions of PTAF on structures passing through it.[6] The mean diameter of PTAF reported by Kapur *et al*.,[13] Galdames *et al*.,[34] Skrzat *et al*.,[9] and Tubbs *et al*.[14] was 3.46 ± 1.26 mm, 5.2 mm, 8.4 ± 1.79 mm, and 9.42 mm, respectively. The horizontal and vertical diameters of this foramen reported by Patnaik *et al*.[35] were 4.45 and 4.7 mm, respectively. PTAF diameter ranged between 7 and 11 mm in Skrzat *et al*.'s study.[9] The horizontal and vertical diameters of PTAF were found to be 4.79 ± 1.39 mm and 3.21 ± 1.70 mm, respectively, in Natsis *et al*.'s study.[18] In a 2017 meta-analysis, the mean horizontal and vertical diameters for PTAF were reported to be 5.31 mm and 3.56 mm, respectively.[6] Despite measurements were performed on dry bones in the present study, our observations were consistent with these previous reports: the horizontal diameter of PTAF was 4.96 ± 2.24 mm, the vertical diameter was 3.80 ± 2.08 mm, and the length was 6.54 mm. The fact that comparable results were obtained in our study and Pękala *et al*.'s study[6] may be indicative of lack of significant geographical effects.

Relationship between pterygoalar bar/pterygoalar foramen and FO

FO is located on the greater wing of the sphenoid bone in the base of the skull, in close adjacency of the posterior margin of LPL, medial to foramen spinosum, and lateral to foramen lacerum. It provides a connection between the cranial fossa and infratemporal fossa, conveying mandibular nerve, accessory meningeal artery, lesser petrosal nerve, and emissary vein. An accurate understanding of the location of FO is of utmost importance for certain diagnostic and surgical procedures such as electroencephalographic analysis, microvascular decompression with percutaneous trigeminal rhizotomy, and percutaneous biopsy of cavernous sinus tumors.[8] Therefore, radiological guidance is required for visualizing FO and related structures.[15] Otherwise, higher doses of anesthesia may be required to achieve adequate anesthetic efficacy in the trigeminal nerve or its branches.[9]

In Kapur *et al*.'s study[13] of 100 dry skulls, PTAF was lateral to, across, or medial to FO in 40%, 40%, and only 20% of the cases, respectively. Skrzat *et al*.[9] reported that FO may be positioned medial or lateral to FO, and while it was found to cross FO in one case, PTAB's position may vary according to FO and its dimensions may range from short and narrow bony trabecular structures to wider laminae. According to Henry *et al*.,[36] PTAB is generally located lateral to FO or passes underneath FO by dividing it into two parts. Tubbs *et al*.[14] also reported that PTAB was generally lateral to PTAB. Natsis *et al*.[18] observed that PTAB was generally lateral to or crosses FO. In previous studies, PTAB was reported to lie medially, laterally, or inferior to FO.[4,9,20,22] In contrast, PTAB was lateral, inferior, and medial to FO in 17, 15, and 5 of the cases reported by Kavitha Kamath and Vasantha.[5] In our study, PTAB was medial, lateral, inferior, inferolateral, and inferomedial to the foramen in 15 (4.93%), 29 (9.53%), 77 (25.32%), 28 (9.21%), and 3 (0.98%) of the cases, respectively.

In Kapur *et al*.'s study,[13] the distance between PTAB and FO was 3.14 ± 1.82. In our study, the same distance was 7.43 ± 2.58 mm and 7.51 ± 2.50 mm on the right and left, respectively. The observed differences may stem from differences in measurement points as well as geographical and ethnic factors.

Pterygospinous bar incidence and location

In several studies, PTSB was more commonly reported to be present on the left side,[5,14,17,23] except for one study reporting mostly bilateral presence of PTSB.[3]

The incidence of PTSB observed by Harikrishnan[11] in 140 Indian dry skulls was 49%, whereas this figure was 28% in Ryu *et al*.'s[8] study examining dry skulls from Korea (complete and incomplete ossification 1.4% and 16.6%, respectively). Kapur *et al*.,[21] however, found a lower complete ossification rate of 1.31% for PTSB in a total of 305 skull samples from Croatia. Peker *et al*.[15] observed that this bony bridge was present in 8.8% of a sample of dry skulls from Anatolia. This figure for PTSB was 9.61% (5.76% complete and 3.84% incomplete) among 416 dry skull samples from an Indian population in Nayak *et al*.'s study.[37] Rosa *et al*.[4] examining the radiographies obtained from 93 dry skulls, identified the presence of pterygospinous ligament in 27.97% of the radiographs, 19.36% being incompletely, and 8.61% being completely ossified.

Wood and Jones[38] found ossification of pterygospinous ligament in 8% of a sample from Hawaii. Lang and

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Hetterich[39] reported ossified pterygospinous ligament in 12%–13% of their samples from an African population. According to Shaw,[17] approximately 1 out of 10 adults may harbor such a pattern of ossification. Kavitha Kamath and Vasantha[5] found PTSB only in 26.83%, PTAB only in 58.54%, and both bony bars in 14.63% of 100 dry skull samples. Antonopoulou *et al*.[25] found a PTSB frequency of 25% and a completely ossified PTSB frequency of 2% in 100 dry skulls. The incidence of complete ossification of PTSB in studies by Kapur *et al*.,[13] Tubbs *et al*.,[14] Civinini,[2] Antonopoulou *et al*.,[25] Peker *et al*.,[15] and Rosa *et al*.[4] was 4%, 1.3%, 2.3%, 2%, 8.8%, and 8.61%, respectively. Matys *et al*.[3] found that 5.8% and 22% of their samples had complete or incomplete ossification of PTSB, respectively, and that this was more common than PTAB. Henry *et al*.,[36] in their meta-analysis, observed a higher rate of PTSB in Caucasians than Africans (10.7% vs. 2.78%). Henry *et al*.,[36] in their study, measured the length and width of PTSB as 7.48 mm and 3.06 mm, respectively. In Henry *et al*.'s[36] meta-analysis, the authors concluded that the general prevalence of PTSB was quite high. Iwanaga *et al*.[31] examined 15 cadaveric samples and found that 50.0% of them harbored PTSB or the ligament. In our study, the rate of complete and incomplete ossification of PTSB was 0.6% and 6.9%, respectively, and these figures were lower than those observed for PTAB. It is interesting to note that the rate of complete ossification of PTSB in this sample of dry skulls from Western Anatolia is lowest as compared to other previous reports.

Pterygospinous bar incidence and location

No consensus exists regarding the structures conveyed through PTSF. According to Henry *et al*.,[36] branches of the mandibular nerve supplying temporal, masseter, and lateral pterygoid muscles pass through PTSF. While Peker *et al*.[15] reported that medial pterygoid nerves and vessels passed through this foramen, Henry *et al*.[36] mentioned the passage of the medial pterygoid nerve and some vessels of the pterygoid venous plexus. Harikrishnan[11] observed an unusually large PTSF in 140 dry skulls from an Indian population and discussed its potential clinical implications.

Complete pterygospinous foramen

The lowest incidence (i.e., 0%) for this structure was reported by Das and Paul,[40] whereas Rosa *et al*.[4] observed the highest, i.e., 8.61%, in a Brazilian population. The same figure was 5.5% in an Anatolian population, as reported by Peker *et al*.[15] Again, this was present in 0.3% of the Indian samples in Singh's study[20] and in 1% in Kavitha Kamath and Vasantha's study.[5] The highest incidence reported in India was 5.76%, based on Nayak *et al*.'s study.[37] Kapur *et al*.[13] identified the presence of PTSF in 4% of 100 dry human skulls. De Froe and Wagenaar,[41] in their anatomical study of dry skulls from European populations, observed that 5% of the skulls harbored PTSF.

Saran *et al*.[22] found a complete ossification of PTSF in 1.2% of 80 skulls, whereas Henry *et al*.,[36] in their meta-analysis of 35 studies, found a complete PS bar rate of 4.4%. In Kapur *et al*.'s study[21] in a Bosnian population, the rate of PTSF was lower (1.31%). In our study, the incidence of PTSF formed by complete PTSB was 0.6%.

Incomplete pterygospinous foramen

The lowest incidence, 1%, was reported by Das and Paul,[40] as compared to the highest incidence of 19.36% reported by Rosa *et al*.[4] in a Brazilian population. The reported figures from India are 8.5% in Singh's study[20] and 16% in Kavitha Kamath and Vasantha's study.[5] Saran *et al*.[22] found that 7.5% of 80 skulls examined harbored an incomplete pterygospinous ligament. In Henry's *et al*.'s[36] meta-analysis of 28 studies, 11.6% of the samples had PS incomplete bar. This figure was 6.9% in the current study.

Pterygospinous foramen morphometry

In Henry's *et al*. meta-analysis,[36] the average horizontal and vertical diameters of PTSF were reported to be 9.05

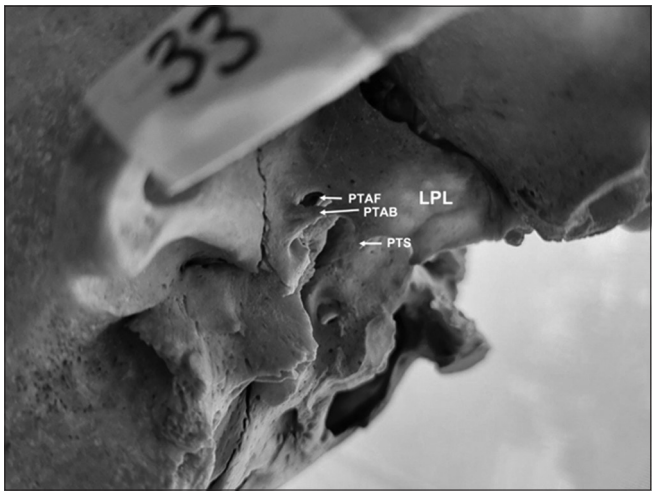


Figure 1: Pterygoalar foramen, complete pterygoalar bar, and incomplete pterygospinous bar in dry skull. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar, PTS: Pterygospinous

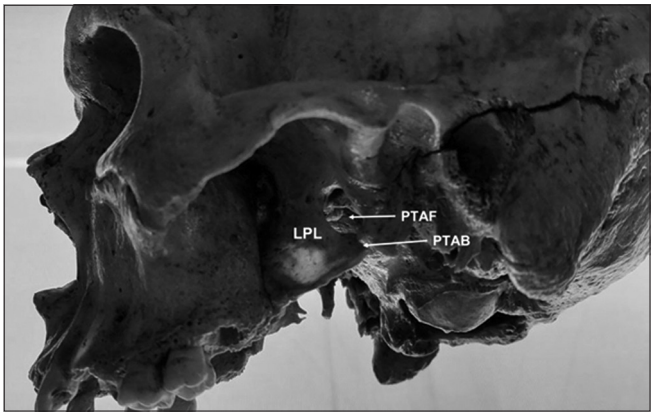


Figure 2: A very large pterygoalar foramen in dry skull and a highly thickened complete pterygoalar bar. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar

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and 5.75 mm, respectively. According to that study, dimensions of PTSF may vary, even in the same skull with bilateral presence of this structure. Furthermore, it may emerge as a large foramen (diameter of up to 10 mm) or may be divided into five separate foramens with varying dimensions.[36] The mean diameters/dimensions for PTSF reported by Kapur *et al*.,[13] Jansirani *et al*.,[12] and Galdames *et al*.[34] were 8.77 ± 1.53 mm, 7.5 mm × 7 mm, and 10.63 mm × 7.37 mm, respectively. The horizontal diameter of PTSF in the right and left sides was approximately 4 mm in Nayak *et al*.'s study.[37] In our study, the vertical diameter of PTSB was 3.20 ± 0.69 mm, and the horizontal diameter was 3.70 ± 0.23 mm [Table 2].

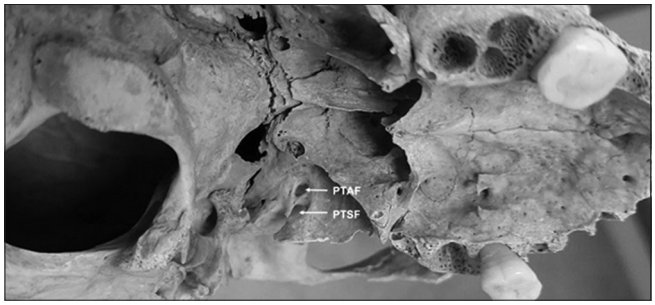


Figure 3: Pterygoalar foramen and pterygospinous foramen occurring concurrently in dry skull. PTAF: Pterygoalar foramen, PTSF: Pterygospinous foramen



Figure 4: Pterygoalar foramen and complete pterygoalar bar in dry skull. LPL: Lateral pterygoid lamina, PTAF: Pterygoalar foramen, PTAB: Pterygoalar bar



Figure 5: Occurrence of incomplete pterygoalar bar in dry skull. LPL: Lateral pterygoid lamina, PTAB: Pterygoalar bar

The relationship between pterygospinous bar/pterygospinous foramen and FO

Previous studies reported that PTSB was located medially or inferiorly relative to FO.[4,9,20,22] However, in Kavitha Kamath and Vasantha's study[5] of 100 dry skulls, PTSB was found to cross FO and was inferiorly (13 samples) or medially (5 samples) located. In contrast with PTAB, which is located laterally to or passes under FO dividing it into two parts, PTSB is located medially to or underneath FO.[18,36]

In the radio-anatomic study of Rosa *et al*.[4], PTSF was found to be located medially to FO in almost all cases, whereas Kapur *et al*.[13] found lateral position of PTSF in 50%, medial in 25%, and superimposed in 25%. According to the findings of Kapur *et al*.[13] in 100 dry skulls, PTSF was present in 4% of the samples, predominantly on the right side. In 50% of the cases, PTSF was located lateral to FO, whereas it was located medially in 2% and coursed across FO in 25%. In our study of 152 skulls, we observed PTSF in only two cases and on the left side, one of which occurred in conjunction with PTAF [Figure 3].

Conclusion

Although human populations have a low incidence of PTAB and PTAF, it appears that improving our understanding regarding the morphology and topography of these structures may have some clinical relevance. Better characterization of the variability of human morphology according to geographical and other factors is a prerequisite to improve surgical performance and to achieve further developments in medicine. Information on the ossification status of the ligaments in question is required for improved interpretation of radiological images in patients with trigeminal neuralgia as well as for better surgical planning and management strategies in procedures such as transfacial needle approaches requiring access to infratemporal fossa and parapharyngeal area. Close proximity of PTAB and PTSB to FO and occasional presence of the related foramen may be highly important for neurosurgeons, anesthesiologists, radiologists, craniofacial surgeons, and dental care specialists due to potential nerve compression. As opposed to previous reports, the width and thickness of PTAB were measured for the first time in the current study. We believe that the information provided herein may also prove to be valuable for cranial and maxillofacial surgeons when planning surgery in the skull base through the infratemporal fossa approach.

Acknowledgments

The authors wish to thank Prof. Nukhet Gocmen Karabekir, MD, and Bayram Aydinlik, MD, for their help and contribution.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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References

1. Hyrtl J. Regarding the crotaphitico-buccinatorium formen in humans. Sitzungsb Akad Wissensch Math-Naturw Cl, Wien 1862;46:111.
2. Civinini F. Pterygospinous ligament found, described demonstrated by Filippo Civinini from Pistoia in. Arch sc Med Fis Toscane 1837;1:381-7.
3. Matys T, Ali T, Zaccagna F, Barone DG, Kirollos RW, Massoud TF. Ossification of the pterygoalar and pterygospinous ligaments: A computed tomography analysis of infratemporal fossa anatomical variants relevant to percutaneous trigeminal rhizotomy. J Neurosurg 2019;132:1942-51.
4. Rosa RR, Faig-Leite H, Faig-Leite FS, Moraes LC, Moraes ME, Filho EM. Radiographic study of ossification of the pterygospinous and pterygoalar ligaments by the hirtz axial technique. Acta Odontol Latinoam 2010;23:63-7.
5. Kavitha Kamath B, Vasantha K. Anatomical Study of pterygospinous and pterygoalar bar in human skulls with their phylogeny and clinical significance. J Clin Diagn Res 2014;8:C10-3.
6. Pękala PA, Henry BM, Pękala JR, Frączek PA, Taterra D, Natsis K, *et al.* The pterygoalar bar: A meta-analysis of its prevalence, morphology and morphometry. J Craniomaxillofac Surg 2017;45:1535-41.
7. Rossi AC, Freire AR, Manoel C, Prado FB, Botacin PR, Caria PH. Incidence of the ossified pterygoalar ligament in brazilian human skulls and its clinical implications. J Morphol Sci 2011;28:69-71.
8. Ryu SJ, Park MK, Lee UY, Kwak HH. Incidence of pterygospinous and pterygoalar bridges in dried skulls of Koreans. Anat Cell Biol 2016;49:143-50.
9. Skrzat J, Walocha J, Srodek R. An anatomical study of the pterygoalar bar and the pterygoalar foramen. Folia Morphol (Warsz) 2005;64:92-6.
10. Bergman RA, Afifi AK, Miyauchi R. Illustrated encyclopedia of Human Anatomic Variation: opus V: skeletal systems: cranium. Illustrated Encyclopedia of Human Anatomic Variation; 1995.
11. Harikrishnan P. Analysis of clinical significance of the pterygospinous and pterygoalar bars. J Craniofac Surg 2020;31:e449-51.
12. Jansirani D, Mugunthan N, Anbalagan J, Sudha R, Shivadeep S. A study on ossified pterygospinous and pterygoalar ligaments in Indian skulls. Natl J Basic Med Sci 2012;3:103-7.
13. Kapur E, Ciric D, Talovic E. Ossification of the pterygospinous and pterygoalar ligaments and their clinical relevance. Folia Med Fac Med Univ Saraev 2017;52:9-15.
14. Tubbs RS, May WR Jr., Apaydin N, Shoja MM, Shokouhi G, Loukas M, *et al.* Ossification of ligaments near the foramen ovale: An anatomic study with potential clinical significance regarding transcutaneous approaches to the skull base. Neurosurgery 2009;65:60-4.
15. Peker T, Karaköse M, Anil A, Turgut HB, Gülekon N. The incidence of basal sphenoid bony bridges in dried crania and cadavers: Their anthropological and clinical relevance. Eur J Morphol 2002;40:171-80.
16. Peuker ET, Fischer G, Filler TJ. Entrapment of the lingual nerve due to an ossified pterygospinous ligament. Clin Anat 2001;14:282-4.
17. Shaw JP. Pterygospinous and pterygoalar foramina: A role in the etiology of trigeminal neuralgia? Clin Anat 1993;6:173-8.
18. Natsis K, Piagkou M, Skotsimara G, Totlis T, Apostolidis S, Panagiotopoulos NA, *et al.* The ossified pterygoalar ligament: An anatomical study with pathological and surgical implications. J Craniomaxillofac Surg 2014;42:e266-70.
19. Piagkou MN, Demesticha T, Piagkos G, Androutsos G, Skandalakis P. Mandibular nerve entrapment in the infratemporal fossa. Surg Radiol Anat 2011;33:291-9.
20. Singh R. Ossification of pterygospinous and pterygoalar ligaments and their clinical significance: An anatomic study. J Craniofac Surg 2022;33:1603-6.
21. Kapur E, Dilberović F, Redzepagić S, Berhamović E. Variation in the lateral plate of the pterygoid process and the lateral subzygomatic approach to the mandibular nerve. Med Arh 2000;54:133-7.
22. Saran RS, Ananthi KS, Subramaniam A, Balaji MT, Vinaitha D, Vaithianathan G. Foramen of civinini: A new anatomical guide for maxillofacial surgeons. J Clin Diagn Res 2013;7:1271-5.
23. Chouke KS. On the incidence of the foramen of civinini and the porus crotaphitico-buccinatorius in American whites and negroes; observations on 2745 additional skulls. Am J Phys Anthropol 1947;5:79-86.
24. Daimi SR, Siddiqui AU, Gill SS. Analysis of foramen ovale with special emphasis on pterygoalar bar and pterygoalar foramen. Folia Morphol (Warsz) 2011;70:149-53.
25. Antonopoulou M, Piagou M, Anagnostopoulou S. An anatomical study of the pterygospinous and pterygoalar bars and foramina – Their clinical relevance. J Craniomaxillofac Surg 2008;36:104-8.
26. Lepp FH, Sandner O. Anatomic-radiographic study of ossified pterygospinous and “innominate” ligaments. Oral Surg Oral Med Oral Pathol 1968;26:244-60.
27. Pinar Y, Arsu G, Aktan-lkiz ZA. The pterygospinous and the pterygoalar bridges. Sendrom 2004;18:66-9.
28. Suazo I, Matamala D, Smith R. Anatomical study of the pterygospinous and pterygoalar bony bridges and foramens in dried crania and its clinical relevance. Int J Morphol 2010;28:405-8.
29. Chakravarthi KK, Babu KS. An anatomical study of the pterygo-alar bar and porus crotaphitico buccinatorius. Int J Med Health Sci 2012;1:3-9.
30. Chouke KS, Hodes PJ. The ptergoalar bar and its recognition by roentgen methods in trigeminal neuralgia. Am J Roentgenol Radium Ther 1951;65:180-2.
31. Iwanaga J, Clifton W, Dallapiazza RF, Miyamoto Y, Komune N, Gremillion HA, *et al.* The pterygospinous and pterygoalar ligaments and their relationship to the mandibular nerve: Application to a better understanding of various forms of trigeminal neuralgia. Ann Anat 2020;229:151466.
32. De Villiers H. The skull of the African Negro: A biometrical and morphological study: (Thesis…. University of the Witwatersrand, 1963) Johannesburg: Witwatersrand University Press; 1968.
33. Zakrzewska JM. Medical management of trigeminal neuralgia. Br Dent J 1990;168:399-401.

34. Galdames SI, Matamala Z, Smith D. Anatomical Study of the pterygospinous and pterygoalar bony bridges and foramens in dried crania and its clinical relevance. Int J Morphol 2010;28:405-8.
35. Patnaik VV, Singla RK, Sanju B. Bilateral pterygoalar bar and porus crotaphitico buccinatorius: A case report. J Anat Soc India 2001;50:161-2.
36. Henry BM, Pękala PA, Frączek PA, Pękala JR, Natsis K, Piagkou M, *et al.* Prevalence, morphology, and morphometry of the pterygospinous bar: A meta-analysis. Surg Radiol Anat 2020;42:497-507.
37. Nayak SR, Saralaya V, Prabhu LV, Pai MM, Vadgaonkar R, D'Costa S. Pterygospinous bar and foramina in Indian skulls: Incidence and phylogenetic significance. Surg Radiol Anat 2007;29:5-7.
38. Wood-Jones F. The non-metrical morphological characters of the skull as criteria for racial diagnosis: Part II: The non-metrical morphological characters of the Hawaiian skull. J Anat 1931;65:368-78.
39. Lang J, Hetterich A. Contribution on the postnatal development of the processus pterygoideus. Anat Anz 1983;154:1-31.
40. Das S, Paul S. Ossified pterygospinous ligament and its clinical implications. Bratisl Lek Listy 2007;108:141-3.
41. De Froe A, Wagenaar JH. Meaning of the porus crotaphiticobuccinatorius and the foramen pterygospinosum for neurology and radiology. Fortschr Röntgenstr 1935;52:64-9.

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