ORIGINAL RESEARCH

Evaluation of the Foramen of Civinini and Foramen of Hyrtl in the Human Skull Base: An Osteological Study

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Abstract

Objective: The infratemporal region of the skull base is traversed by critical neurovascular structures, and anatomical variations such as ossified cranial base ligaments, which can pose significant clinical challenges. The foramen of Civinini and Hyrtl, formed by ossification of the pterygospinous and pterygoalar ligaments respectively, are infrequent but surgically relevant entities. This study aims to investigate the anatomical variations in the infratemporal region, with a focus on the ossified ligaments and their clinical implications.

Methods: This osteological study was conducted on 134 adult dry human skulls of unknown age and sex. Each skull was examined bilaterally for the presence of the foramen of Civinini and the foramen of Hyrtl. Parameters analyzed included presence or absence, laterality, completeness of ossification, and their anatomical relationship to the foramen ovale. Notable morphological variations were documented photographically.

Results: The foramen of Civinini was observed in 9 skulls (6.7%), predominantly unilaterally (78%), with complete ossification in 7 cases. The foramen of Hyrtl was identified in 3 skulls (2.2%), all of which were unilateral. Co-existence of both foramina was noted in a single skull, where the foramen of Hyrtl appeared fused with the foramen of Civinini. Comparative analysis using Fisher's exact test showed no statistically significant differences between the two foramina in terms of laterality or ossification pattern.

Conclusion: Although uncommon, the foramina of Civinini and Hyrtl represent important anatomical variations with potential implications for neurosurgical and maxillofacial procedures. Their presence may hinder access during percutaneous interventions and contribute to unexpected anesthetic or neural complications. Awareness of these variants is essential in surgical planning and radiological interpretation.

Keywords: Sphenoid Bone; Ossification; Ligaments; Mandibular Nerve

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Introduction

The infratemporal region, located at the base of the skull, is anatomically complex and traversed by vital neurovascular structures, including branches of the mandibular division of the trigeminal nerve. Variations in this region, such as ossification of cranial base ligaments, may pose significant challenges to surgical access and nerve block procedures (1). Notably, ossified ligaments may obstruct established surgical corridors and interfere with transcutaneous or skull base operative routes. Earlier anatomical records suggest that Giovanni Filippo Ingrassias (1510–1580) may have been the first to observe this structure (2). In 1835, the Italian anatomist Filippo Civinini identified a bony projection arising from the lateral pterygoid plate, later termed the spine of Civinini. This osseous spur occasionally extends toward the spine of the sphenoid, creating a potential bony bridge. In 1837, he further described the pterygospinous ligament connecting these two points (Figure 1). When this ligament undergoes ossification, it forms the foramen of Civinini or pterygospinous foramen, typically located medial to the foramen ovale (3). The reported incidence of pterygospinous ligament ossification varies widely. Civinini et al. noted it in 2–3% of their specimens, while recent studies report complete ossification in 2–6% and incomplete ossification in up to 12% of skulls (4,5). Approximately 10% of adult skulls have been reported to exhibit some degree of ossification of the pterygospinous ligament, ranging from minor spicules to partially or fully formed bony bridges (6). When present, this foramen may transmit branches of mandibular nerve (especially the nerve to medial pterygoid or lingual nerve) and small branches of the maxillary artery, leading to entrapment neuropathies such as trigeminal neuralgia, masticatory muscle spasm, myofascial pain syndromes, restricted mandibular movements, and sensory disturbances in the mandibular nerve distribution. In 1862, German anatomist Josef Hyrtl described the pterygoalar ligament (Figure 2), which stretches from the inferior surface of the greater wing of the sphenoid to the root of the lateral pterygoid plate. Its ossification gives rise to the foramen of Hyrtl, also known as the foramen masticatorium or crotaphiticobuccinatorium, typically located lateral to the foramen ovale (7).

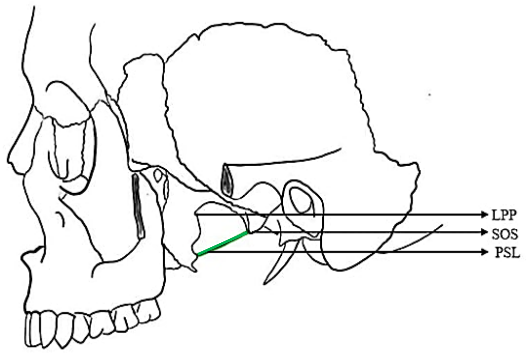

Figure 1: Lateral view of the skull showing the pterygospinous ligament (green). LPP - Lateral pterygoid plate, PSL - Pterygospinous ligament SOS - Spine of sphenoid

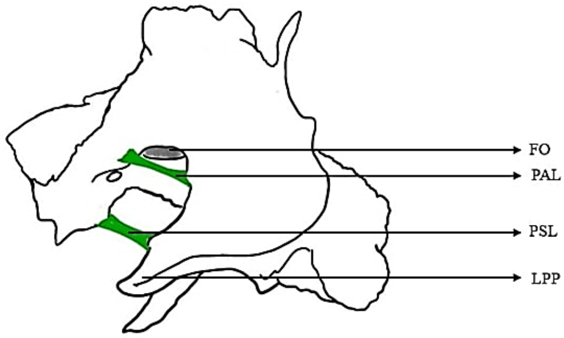

Figure 2: Basal view of the sphenoid region showing ossified cranial base ligaments (green). FO-Foramen ovale , PAL-Pterygoalar ligament, PSL-Pterygospinous ligament, LPP - Lateral pterygoid plate

This foramen may transmit branches of the mandibular nerve, including the nerve to the masseter and deep temporal nerves, and is observed in approximately 1% of the adult population (1, 6). Despite the known occurrence of these foramina, their co-existence, degree of completeness, and precise spatial relationship to the foramen ovale remain insufficiently documented, especially in Indian skulls. These anatomical variants are of considerable interest to anatomists, oral and maxillofacial surgeons, and neurosurgeons. Hence, this study aimed to determine the incidence, laterality and ossification patterns of the foramina of Civinini and Hyrtl in Indian skulls and to analyze their anatomical relationships with the foramen ovale.

Methods

This study involved 134 adult dry human skulls of unknown age and sex, obtained from the Department of Anatomy. Ethical approval was not necessary since the bone specimens were sourced from donated bodies through an established donation program. All procedures adhered to the institution's ethical guidelines and legal standards for the use of donated human tissues. Skulls with visible damage, deformity, or missing anatomical landmarks in the region of interest were excluded from the study. Each skull was examined bilaterally for the presence of the foramen of Civinini and the foramen of Hyrtl. The study assessed the presence or absence of the foramina, the pattern of ossification (complete or incomplete), and their laterality (unilateral or bilateral). The anatomical positions of the foramina were recorded relative to the foramen ovale. Patency was assessed using a flexible PVC (Polyvinyl Chloride) wire probe, and representative specimens were photographed with a Canon DSLR camera under standardized lighting conditions. Special attention was given to cases showing coexistence or fusion of both foramina. All observations were independently verified by two observers, and discrepancies were resolved by consensus. Interobserver reliability showed excellent agreement with a Cohen’s kappa value of 0.86 ($p < 0.001$).

Statistical analysis

Data were presented as counts and percentages. Comparative analyses for categorical variables (laterality and ossification type) were performed using Fisher’s exact test, suitable for small sample sizes. These analyses were conducted using Jamovi (version 2.7.6) (8). Differences in proportions with 95% confidence intervals were calculated. A p-value < 0.05 was considered statistically significant.

Results

The presence of ossified ligaments forming the foramen of Civinini and the foramen of Hyrtl was documented during bilateral inspection of 134 adult human skulls (Figure 3). As summarized in Table 1, the foramen of Civinini was more commonly encountered, with a predominance of unilateral cases over bilateral. Among the unilateral foramina, complete ossification was more frequent than incomplete (Figure 4). The foramen of Hyrtl was distinctly less prevalent and appeared only unilaterally in a small number of cases (Figure 5). Laterality showed no consistent side dominance for either foramen. Notably, a co-existence of both foramina was identified in one skull, where the foramen of Hyrtl appeared fused with the foramen of Civinini (Figure 5). This unusual configuration displaced the latter laterally from its expected location medial to the foramen ovale.

No accessory foramina or aberrant bony spurs were found in the remaining skulls. The findings suggest variability in the incidence and morphology of these foramina, underscoring the clinical importance of preoperative recognition and radiological assessment. Fisher's exact test showed no significant association between foramen type (Civinini vs Hyrtl) and laterality (bilateral vs unilateral) (p = 1.000). The difference in the proportion of bilateral versus unilateral occurrence between the two foramen types was 0.22 (95% CI: –0.049 to 0.49), which was not statistically significant. With respect to ossification pattern, complete ossification was observed more frequently in the foramen of Civinini (7 cases) compared to the foramen of Hyrtl (2 cases), while incomplete ossification was seen in 2 and 1 cases, respectively. Fisher's exact test showed no significant association between foramen type and completion of ossification (p = 1.000). The difference in proportions was 0.11 (95% CI: –0.48 to 0.71), which was not statistically significant.

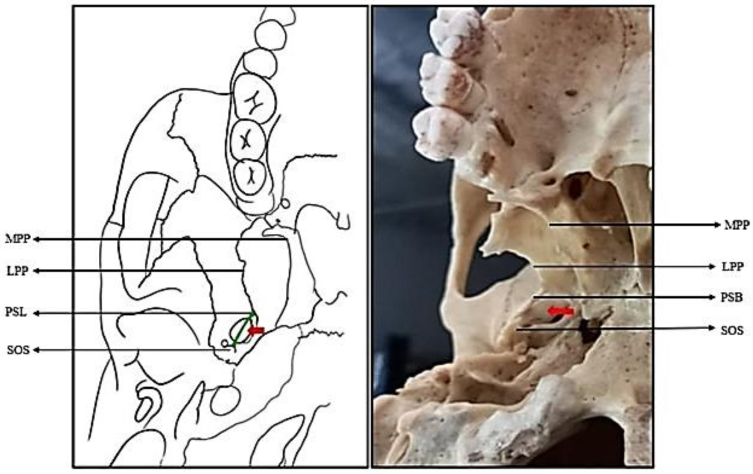

Figure 3. Inferior view of Skull showing diagrammatic representation (left) and bony specimen (right) showing the ossified pterygospinous ligament (PSL) to form foramen of civinini (Red arrow). MPP - Medial pterygoid plate, LPP - Lateral pterygoid plate, PSL - Pterygospinous ligament, PSB - Pterygospinous bar, FO - Foramen ovale, SOS - Spine of sphenoid

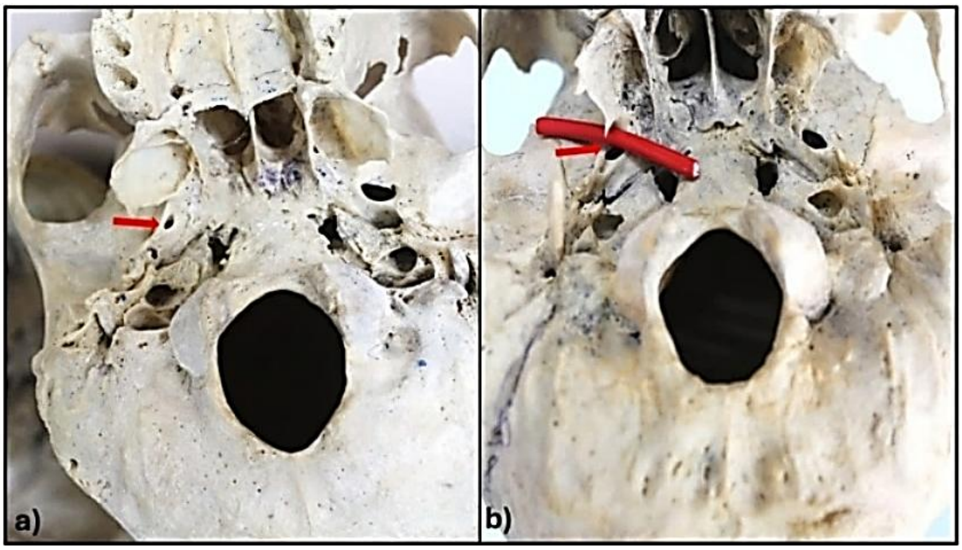

Figure 4: Inferior view of skull showing (a) complete foramen of Civinini and (b) incomplete foramen of Civinini formed by ossification of the pterygospinous ligament.

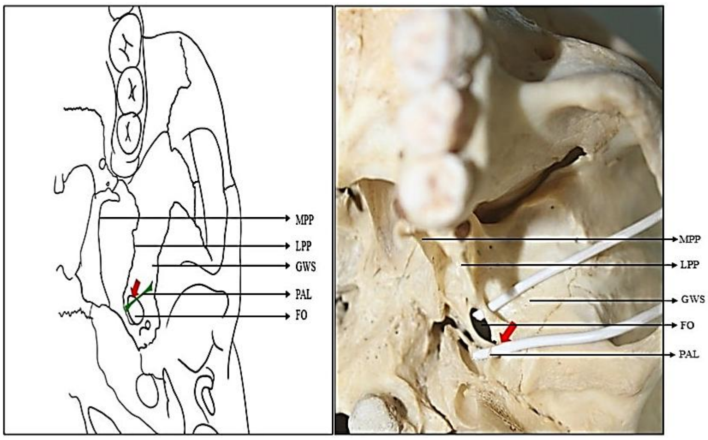

Figure 5: Inferior view of skull showing diagrammatic representation (left) and bony specimen (right) demonstrating the ossified pterygoalar ligament (PAL) forming the foramen of Hyrtl (red arrow). MPP - Medial pterygoid plate, LPP - Lateral pterygoid plate, GWS - Greater wing of sphenoid, FO - Foramen ovale, and PAL - Pterygoalar ligament.

Table 1: Distribution of variants of the cranial base ligaments

Type of Foramen	n (%)	Laterality		Extent of Ossification	
		Unilateral	Bilateral	Complete	Incomplete
Foramen of Civinini	9(6.7%)	7 (5.2%)	2 (1.5%)	7 (5.2%)	2 (1.5%)
Foramen of Hyrtl	3 (2.2%)	3 (2.2%)	-	2 (1.5%)	1 (0.7%)

Table 2. Prevalence of the foramen of Civinini and foramen of Hyrtl in previous studies

Study	Method	Foramen of Civinini (%)	Foramen of Hyrtl (%)	Extent of Ossification
Nayak et al. (4)	Dry skull	9.6	—	5.8% complete, 3.8% incomplete
Matys et al. (16)	Radiological (CT scan)	17.5	5	-
Oliveira et al. (9)	Dry skull	8.8	2.2	Incomplete Ps more common; Hyrtl bilateral in one skull
Aksu & Karabekir (8)	Dry skull	9.2	11.5	Pa: 1.3% complete, 10.2% incomplete; Ps: 0.7% complete, 8.5% incomplete
Yanarates et al. (10)	Radiological (CT scan)	6.57	16.28	Most common: unilateral incomplete; higher in males
Present study	Dry skull	6.7	2.2	Co-existence noted in one skull

*Pa-Pterygoalar; Ps-Pterygospinous

Discussion

Ossified ligaments in the cranial base—manifesting as pterygospinous and pterygoalar bony bars are an underappreciated anatomical phenomenon with significant clinical ramifications. Though often overlooked in standard anatomical descriptions, these structures can influence neural pathways, distort expected anatomy in surgical fields, and contribute to atypical patterns of pain and anaesthetic failure. Their ossification into foramina may reflect not only individual anatomical variation but also traits retained from earlier stages of cranial evolution. As modern skull base surgery and precision imaging evolve, the importance of documenting and understanding such variants becomes increasingly relevant to both anatomists and clinicians. In our study, the foramen of Civinini appeared in 6.7% of skulls and the foramen of Hyrtl in 2.2%. These findings are supported by previous osteological studies, with one study reporting a 9.6% prevalence of pterygospinous bony bridges (complete 5.8%, incomplete 3.8%) among 416 Indian skulls (4, 5), while another found 9.2% pterygospinous and 11.5% pterygoalar bars in 100 specimens (9, 10). Radiological studies reflect similar anatomical variability: a recent CT-based study observed a 6.6% prevalence of pterygospinous and 16.3% pterygoalar bars (11), and a meta-analysis of over 14,000 subjects reported 4.4% complete and 11.6% incomplete pterygospinous bars (12). The same analysis also reported a higher prevalence of complete pterygospinous bars in males, with a predominance of unilateral occurrence. Previous studies have reported variable occurrence of the foramen of Civinini and foramen of Hyrtl (Table 2). Although the sensitivity of imaging and osteological studies differs, the comparable prevalence across modalities suggests that these ossified ligaments are consistently present and detectable in diverse populations.

Although complete ossification was found to be more frequent in foramen of Civinini, this difference was not statistically significant. This suggests that laterality and the ossification pattern is independent from the type of foramen. However, the tendency towards a higher rate of complete ossification in foramen of Civinini could have a crucial clinical implication particularly in creating a surgical corridor where minor bony obstructions can hamper access to the foramen ovale.

Embryology

The pterygospinous and pterygoalar ligaments originate from the mesenchyme of the first branchial arch, near Meckel's cartilage (13). While these ligaments typically remain fibrous, they may undergo membranous ossification under the influence of bone morphogenetic proteins (BMPs) and transcription factors such as RUNX2 (14). Ossification is generally considered a postnatal process, with its extent influenced by genetic predisposition, muscular tension, and age-related changes (1).

From an anthropological and evolutionary perspective, these foramina have been hypothesized to represent atavistic remnants. Studies have suggested that similar bony bridges are more prevalent in non-human primates, indicating that their presence in humans may reflect primitive developmental pathways (15). Earlier work also described such epigenetic traits as part of skull variability across populations, emphasizing their relevance in anthropological research (16). The variations in the ossification patterns may be related to differences in developmental ossification centers and the timing of their fusion. The presence of incomplete versus complete ossification could represent differing stages of ossification arrest, or genetic and environmental influences on cranial base development.

Clinical Implications

The presence of these foramina may carry significant implications. A completely ossified pterygospinous ligament forming the foramen of Civinini may obstruct the needle path during percutaneous approaches to the foramen ovale, affecting procedures such as radiofrequency rhizotomy in trigeminal neuralgia (17). Moreover, the presence of a bony bar in this region may account for failed inferior alveolar nerve blocks or unexpected resistance during mandibular nerve anaesthesia (18). Even incomplete bars may compress neural structures, leading to unexplained facial pain or paresthesia. The foramen of Hyrtl, lying lateral to the foramen ovale, poses challenges in surgical approaches to the infratemporal fossa, particularly during maxillofacial tumor resections, parapharyngeal space surgeries, or vascular dissections. It may transmit neurovascular elements that are at risk during surgical access or contribute to perineural tumor spread (12). Other authors have emphasized the importance of recognizing these anatomical variants when planning lateral skull base approaches, especially during endoscopic-assisted surgeries (17).

CT imaging reveals these bars as distinct bony bridges inferolateral to the foramen ovale, often serving as reference points in percutaneous trigeminal procedures. In clinical practice, recognizing these variants on imaging is crucial to avoid diagnostic misinterpretation or failed anesthetic techniques (19).

In this osteological study of 134 adult human skulls, the foramen of Civinini was identified in 6.7% of specimens, most commonly as a unilateral and completely ossified structure, while the foramen of Hyrtl was observed less frequently (2.2%) and exclusively in a unilateral form. Co-existence of both foramina was rare and was noted in a single skull, where fusion resulted in lateral displacement of the foramen of Civinini. Statistical analysis demonstrated no significant association between foramen type and laterality or ossification pattern. These findings highlight the variability and low prevalence of ossified pterygospinous and pterygoalar ligaments in Indian skulls and provide baseline anatomical data relevant to the infratemporal region.

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

Ethical Approval: Ethical approval was not considered, as our work is on skeletal remains.

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