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Clinical anatomy of the sphenoid bone and its terminology

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Abstract

The sphenoid bone, an unpaired, irregular, and pneumatic (air-filled) component of the neurocranium, is a clinically important landmark, particularly in surgery and radiology. This bone is often regarded as one of the most complex bones of the skull. This literature review aims to compile peer-reviewed articles concerning the anatomy of the sphenoid bone while briefly exploring its clinical relevance. The sphenoid bone consists of a centrally positioned body containing the sphenoidal sinus, as well as three pairs of processes projecting from the body, namely the greater wings, lesser wings, and pterygoid processes. The sphenoid is closely associated with five cranial nerves (CNs II, III, IV, V_1, V_2, and VI) and is adjacent to the pituitary gland. The cavernous sinus, housing the internal carotid artery, lies laterally to the body of the sphenoid. Various neurological conditions, such as injury, inflammation, vascular malformations, aneurysms, and tumors, can either directly impact the sphenoid or occur in close proximity to it. A comprehensive understanding of the anatomy of the sphenoid is indispensable for diagnosing and planning the treatment of these conditions. Therefore, a detailed knowledge of the anatomy of the head, including the sphenoid, is essential in clinical practice. It ensures accurate diagnoses, safe surgical procedures, and effective management of diverse conditions affecting the skull, sinuses, brain, and adjacent structures. Inaccuracies or errors in the diagnosis or treatment of such conditions can lead to adverse patient outcomes, including various complications and delayed management of serious neurological conditions.

Running title: Clinical anatomy of the sphenoid bone

Keywords: sphenoid bone, human anatomy, clinical anatomy, surgery, anatomical terminology

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Introduction

The sphenoid bone, wedged between the frontal, temporal, occipital, and parietal bones, is an irregular, unpaired, and pneumatic (air-filled) bone within the neurocranium. It also articulates with the ethmoid bone, vomer, zygomatic, and palatine bones [1]. The sphenoid bone forms the central part of the cranial base (basicranium) and contributes to the formation of the anterior cranial fossa, the middle cranial fossa, the posterior cranial fossa, the orbit, the nasal cavity, the temporal fossa, the infratemporal fossa, and the pterygopalatine fossa. Its shape somewhat resembles a flying wasp or a bat with its wings extended [2].

Developmentally, the sphenoid forms as the result of fusion of several bones, including the presphenoid, basisphenoid, orbitosphenoid, alisphenoid, and pterygoid [3-5]. After the fusion is complete, the sphenoid consists of a central body housing the sphenoidal sinus and three even processes: greater and lesser wings, and two pterygoid processes [1,2]. The sphenoid bone is a clinically important landmark due to its complex anatomy and its proximity to critical structures of the head. It also plays a central role in safeguarding vital structures of the brain such as the pituitary gland, the optic chiasm, and the internal carotid artery. Moreover, this bone acts as a conduit for five cranial nerves, including the optic (CN II), oculomotor (CN III), trochlear (CN IV), trigeminal (CN V), and abducent (CN VI) nerves. Any pathology or injury affecting the sphenoid can potentially lead to a wide range of neurological symptoms or deficits. Furthermore, the body of the sphenoid contains the sphenoidal sinuses, which are a pair of air-filled cavities. Infections or inflammation in this sinuses can cause headaches, facial pain, and can potentially lead to complications involving nearby structures. Surgeons frequently require access to the sphenoid during various neurosurgical procedures, notably transsphenoidal surgery, which is a common approach for addressing pituitary tumors [6,7]. In medical imaging, particularly within radiology and neurology, the sphenoid serves as a crucial landmark for interpreting various radiological studies, such as computed tomography (CT) and magnetic resonance imaging (MRI) scans of the head. Otolaryngologists and neurosurgeons oftentimes employ endoscopic techniques to diagnose and treat conditions related to the sphenoidal sinuses, including tumors, inflammation, and infections. None of these tasks are possible without a detailed knowledge of the anatomy of the sphenoid bone.

This article focuses on the clinical aspects of the sphenoid bone and its terminology, emphasizing the pivotal role of comprehending the sphenoid and its associated anatomical structures for healthcare professionals spanning various medical specialties.

Body of the sphenoid

The body of the sphenoid, which is approximately cubical in shape, features six surfaces and contains two air sinuses separated by a thin bony septum [8-11]. Its anterior surface and a portion of its inferior surface face the nasal cavity. On the anterior surface, there is a bony ridge known as the sphenoidal crest (**Fig. 1**), which articulates with the perpendicular plate of the ethmoid

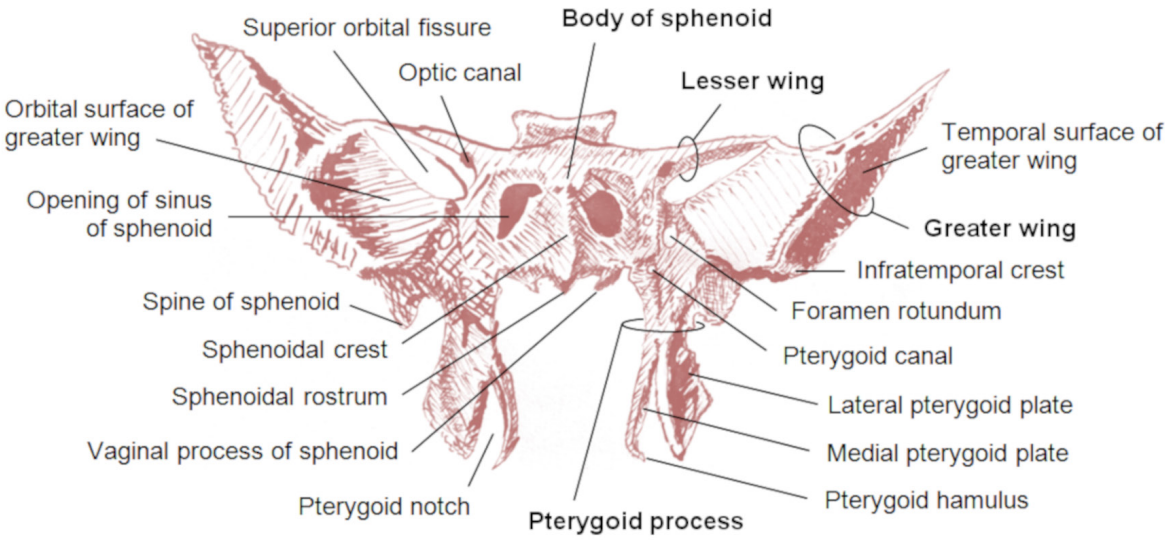

FIGURE 1 Sphenoid bone (anterior view). The figure was created by the author

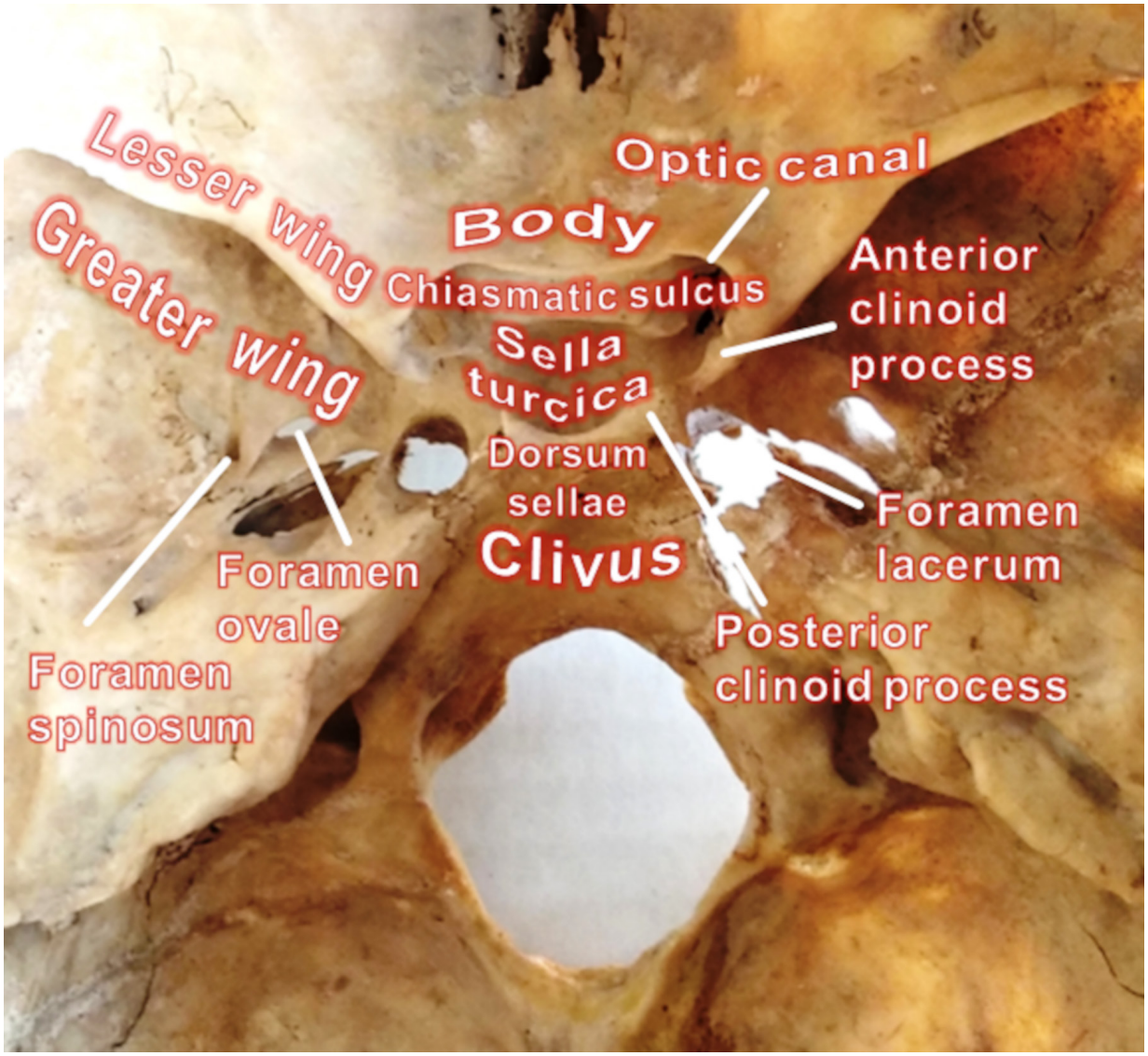

FIGURE 2 Adult skull, internal surface of cranial base. The sphenoid bone contributes to the formation of the floor of the cranial cavity. The sella turcica is bounded by the tuberculum sellae anteriorly and the dorsum sellae posteriorly. The median depression, which accommodates the pituitary gland (hypophysis), is called the hypophyseal fossa. The middle clinoid processes are visible on each side of the tuberculum sellae. The figure was created by the author

bone. Extending downward from the sphenoidal crest is the sphenoidal rostrum, which articulates with the alae of the vomer. Adjacent to the sphenoidal crest, two thin curved platescalled the sphenoidal conchae (or 'sphenoidal turbinated processes') are present. Each plate has an aperture, representing the opening of the sphenoidal sinus. The sinuses communicate anteriorly through these rounded openings with the sphenoethmoidal recess of the nasal cavity.

The superior surface forms the floor of the cranial cavity, specifically the anterior and middle cranial fossa (**Fig. 2**). From anterior to posterior, it consists of the sphenoidal plane, the sphenoidal yoke (jugum sphenoidale) that connects the lesser wings, the chiasmatic sulcus (sulcus chiasmaticus, TA 2019; sucus prechiasmaticus, TA 1998), which lodges the optic chiasm and continues bilaterally as the optic canal for the optic nerve and the ophthalmic artery.

The chiasmatic sulcus is separated by the tuberculum sellae from the hypophyseal fossa that is occupied by the pituitary gland (hypophysis). The sella turcica is bounded by the tuberculum sellae anteriorly and the dorsum sellae posteriorly, which forms the posterior wall of the hypophyseal fossa. The median depression, which houses the pituitary gland, is called the hypophyseal fossa (or hypophysial fossa). The size, shape, and anatomical variations of the sella turcica have been the subject of extensive studies due to their clinical significance [12-17]. Two posterior clinoid processes extend from either side of the dorsum sellae.

The lateral surfaces of the body are inaccessible as three pairs of processes project lat-

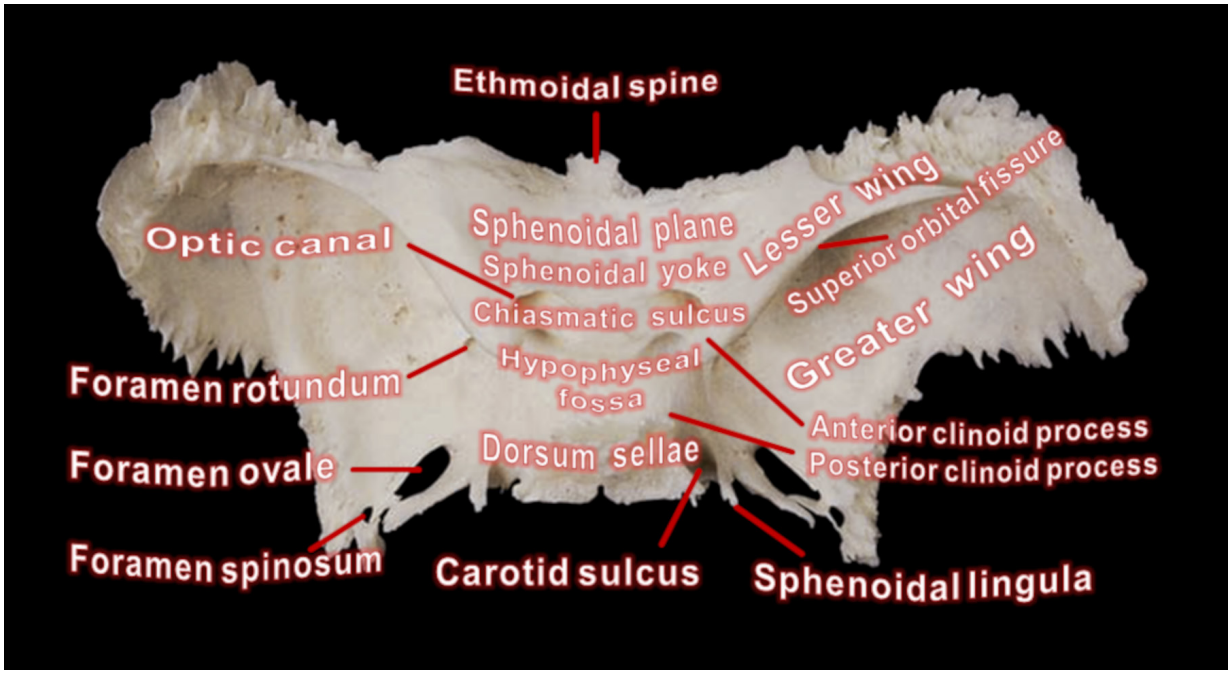

FIGURE 3 Bony landmarks of the sphenoid bone (superior view). The arcade of four foramina perforates the roots of the cerebral surfaces of the greater wings on each side of the body of the sphenoid. These openings are: the superior orbital fissure (for CNs III, IV, V1, and VI), foramen rotundum (for V2), foramen ovale (for V3), and foramen spinosum (transmitting the meningeal branch of V3, as well as middle meningeal artery and vein). The figure was created by the author

erally from them, i.e. the lesser wings in the anterior aspect, the greater wings in the posterior aspect, and the pterygoid processes in the inferior aspect. Just above the attachment of the greater wing, there is the carotid sulcus (sometimes referred to as the carotid groove), stretching from the foramen lacerum to the medial aspect of the anterior clinoid process (**Fig. 2, 3).** The sphenoidal lingula is a bony ridge that projects at the posterior edge of the carotid sulcus on its lateral side. The carotid sulcus contains the internal carotid artery that is surrounded by the cavernous sinus and gives off the meningohypophyseal artery, the inferolateral trunk, and the small capsular arteries.

The cavernous sinus comprising the internal carotid artery and the cranial nerves (that is, the abducent nerve, CN VI, situated lateral to the artery, as well as the oculomotor, CN III, trochlear, CN IV, and trigeminal nerves, CN V, positioned in the lateral wall of the sinus) lies on each side of the body of the sphenoid [18-23]. These venous sinuses receive blood from the pituitary gland, middle cerebral vein, sphenoparietal sinus, emissary veins from the pterygoid plexus of veins in the infratemporal fossa, as well as from the orbit via the ophthalmic veins and the central vein of the retina. Notably, these complex connections provide pathways for infections to pass from extracranial sites into intracranial locations, which is sometimes referred to as the 'danger triangle of the face', as infections from the face can spread to the brain, causing various health issues such as inflammation, meningitis, cavernous sinus thrombosis, and brain abscess, which can be the cause of death if not treated with antibiotics or blood thinners. Both cavernous sinuses are connected by the intercavernous sinuses on the anterior and posterior sides of the pituitary stalk, forming a venous circle around it (the circular sinus). The cavernous sinus drains into the superior and inferior petrosal sinuses. The former drains into the transverse sinus, whereas the latter descends along the edge of the occipital bone and drains into the internal jugular vein. Thus, both petrosal sinuses assist in draining the cavernous sinuses. They also receive blood from the cerebellar veins, the veins draining the internal ear as well as the brainstem.

The posterior surface of the sphenoid bone and the basilar part of the occipital bone form the clivus of Blumenbach (**Fig. 2**), on which the pons, the medulla oblongata, and the basilar artery with its branches are lodged. The basilar sinuses connecting the inferior pertorsal sinuses to each other and to the vertebral plexus of veins are situated between the layers of the dura mater on the clivus, just posterior to the sella turcica.

Lesser wings

The lesser wings arise from the anterosuperior aspect of the body of the sphenoid bone

and project laterally as two horizontal plates at the base of which is the optic canal for the optic nerve (CN II) and the ophthalmic artery (**Fig. 1**). The anterior margins of the lesser wings articulate with the posterior margin of the orbital part of the frontal bone via the sphenofrontal suture (**Fig. 2**). The posterior edges of the lesser wings are free and carry on their medial ends the anterior clinoid processes, which are cone-shaped projections on either side of the anterior part of the hypophyseal fossa (**Fig. 3**). Noteworthy, the posterior margins of the lesser wings (so-called the 'sphenoid ridges', including the posterior edges of the lesser wings and the anterior aspect of the chiasmatic sulcus on the body of the sphenoid) separate the anterior cranial fossa from the middle cranial fossa.

The superior orbital fissure, housing the ophthalmic veins, sympathetic fibers from the cavernous plexus, as well as CN III (oculomotor), CN IV (trochlear), CN V_1 (ophthalmic), and CN VI (abducent nerve), is situated between the lesser and greater wings and serves as a passageway from the middle cranial fossa into the orbit (**Fig. 1, 2**). When this fissure is fractured, Rochon-Duvigneaud's syndrome (or superior orbital fissure syndrome) may develop, leading to diplopia (double vision), exophthalmos (bulging of the eye anteriorly out of the orbit), ptosis (drooping of the upper eyelid), or even blindness (loss of vision) if the orbital apex is affected (orbital apex syndrome). This situation requires urgent surgical intervention.

Greater wings

The greater wings spring from the lateral aspect of the body laterally and upwards, forming a part of the cranial base and the lateral wall of the skull. Each greater wing has the following five surfaces, that is, the orbital, maxillary, cerebral, temporal, and infratemporal surface, whose names indicate which cranial part (cavity, surface, or fossa on the lateral wall of the cranium) they face. The last two surfaces are separated by the infratemporal crest (**Fig. 1**), that is, a bony ridge between the vertically-oriented temporal surface and the horizontally-oriented infratemporal surface of the greater wing of the sphenoid bone.

The orbital surface of the greater wing is smooth and faces the orbit. The inferior orbital fissure, housing the infraorbital nerve, the zygomatic nerve, the orbital branches from the sphenopalatine ganglion, as well as the infraorbital vessels and the inferior ophthalmic vein, is located between the lateral wall of the orbit and the floor of the orbit. The sulcus of the auditory tube is a shallow groove on the inferior aspect of the greater wing, just lateral to the root of the pterygoid process. It houses the cartilaginous part of the auditory tube.

Notably, the arcade (crescent) of four foramina formed by the superior orbital fissure (transmitting CNs III, IV, and VI) and foramen rotundum anteriorly (transmitting the maxillary nerve, CN V_2), foramen ovale (transmitting the mandibular nerve, CN V_3), and foramen spinosum posteriorly (transmitting the meningeal branch of the mandibular nerve along with the middle meningeal vessels) in the floor of the middle cranial fossa represents the medial boundary of the infratemporal fossa and the pterygopalatine fossa (**Fig. 2, 3**), and is often used as an important landmark when a superior intracranial approach to the infratemporal fossa is considered.

The sphenoid emissary foramen (of Vesalius) is a small and inconstant opening that is located medially to the foramen ovale in the roof of the infratemporal fossa [24-27]. A small emissary vein passes through this foramen. Similarly, the foramen petrosum (foramen of Arnold, Arnold's foramen) is occasionally present between the foramen spinosum and foramen ovale for transmission of the lesser petrosal nerve [28].

The spine of the sphenoid is situated posteriorly, between the pyramid and the squama of the temporal bone (**Fig. 2**), where it forms a sharp angular spur extending downward and containing the aforementioned foramen spinosum (transmitting middle meningeal artery and vein, and the meningeal branch of the mandibular nerve, CN V_3). The spine of the sphenoid also serves as the attachment site for the cranial end of the sphenomandibular ligament.

Pterygoid processes

The pterygoid process extends inferiorly from the junction of the body of the sphenoid and the greater wing. Each process is made up of two plates: the wider lateral pterygoid plate and the narrower but longer medial pterygoid plate (**Fig. 1**). The lateral and medial surfaces of the lateral pterygoid plate provide attachment for the lateral and medial pterygoid muscles, respectively.

Anteriorly, both plates fuse but they diverge posteriorly, forming the pterygoid fossa, where the deep head of the medial pterygoid muscle originates. The inferior part of the pterygoid fossa is continuous with the pterygoid notch (sometimes referred to as the pterygoid fissure) into which the pyramid process of the palatine bone fits. The pterygoid processes and spines of the sphenoid are anatomically associated with

the structures of the soft palate, which constitute a portion of the roof of the oral cavity.

The base of the pterygoid process is pierced by the pterygoid (Vidian) canal (**Fig. 1**), located just above and medially to the scaphoid fossa [1,2]. The pterygoid canal runs sagittally through the root of the pterygoid process and opens anteriorly into the pterygopalatine fossa [29-31]. Posteriorly, it opens into the middle cranial fossa. It transmits both vessels and nerves of the pterygoid canal. The tensor veli palatini muscle originates in the scaphoid fossa, that is, the oblong depression at the posterosuperior aspect of the medial pterygoid plate.

The pterygospinous process (of Civini) extends sometimes from the posterior edge of the lateral pterygoid plate and serves as the attachment site for the pterygospinous ligament, stretching from the spine of the sphenoid [32].

The superior part of the medial pterygoid process projects medially, forming the vaginal process. The vomerovaginal groove is located on its superior surface, whereas the palatovaginal groove is situated on its inferior surface. The vaginal process is situated below the body of the sphenoid and covers the ala of the vomer. Consequently, the vomerovaginal groove is transformed into the vomerovaginal canal that contains the branches from the pterygopalatine ganglion and small vessels [33]. Similarly, the palatovaginal groove is closed and forms the palatovaginal canal, which transmits the branches of the sphenopalatine artery and the branches from the pterygopalatine ganglion.

The inferior part of the medial pterygoid plate bends over, forming a hook-like process, which is known as the pterygoid hamulus. On its lateral surface is the groove of the pterygoid hamulus (the sulcus of the pterygoid hamulus) for the tendon of the tensor veli palatini muscle.

Anatomic variations

The sphenoid bone exhibits a wide range of anatomical variations, which warrant careful consideration. Among these variations, fusions between the medial clinoid process and the anterior clinoid processes can occur, resulting in the formation of an aperture for the passage of the internal carotid artery. Furthermore, it is possible for the foramen ovale and the foramen spinosum to establish a connection. Medial to the foramen ovale, an additional venous foramen (foramen venosum) may be present, through which the emissary vein courses, piercing the base of the greater wing of the sphenoid bone. An infrequent occurrence is the presence of the foramen petrosum, which is located between the foramen ovale and the foramen spinosum.

In rare instances, the superior orbital fissure may amalgamate either with the foramen rotundum or the optic canal. An exceptional variant involves the doubling of the optic canal, permitting the passage of the optic nerve through one segment and the internal carotid artery through the other. A noteworthy variation can manifest along the posterior edge of the lateral pterygoid plate, where a bony lamina known as the pterygospinous plate or lamina may extend and connectwith the spine of the sphenoid. This may result in the creation of a pterygospinous foramen, allowing the passage of the medial pterygoid nerve, a branch of the mandibular nerve. Normally, a pterygospinous ligament is present instead of this plate, extending between the pterygospinous process and the spine of the sphenoid. To sum up, these intricate variations highlight the remarkable variability of the human body. A comprehensive understanding of such nuances is crucial for clinicians and anatomists alike.

Conclusions

In summary, the sphenoid bone as one of the most complex bones of the skull presents a major challenge for medical students, given its intricate anatomy and central role with the cranial landscape. This complexity, however, underscores its paramount clinical significance. Profound knowledge of the anatomy of the sphenoid bone is indispensable in the field of clinical medicine, serving as the linchpin for precise diagnosis, the execution of safe surgical procedures, as well as the effective management of diverse conditions affecting the skull, sinuses, brain, and surrounding structures.

Ethical approval
This conducted study is not related to either human or animal use.

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Not applicable.

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Conflict of interest
The authors declare no conflict of interest.

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