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Chapter

Anatomical Guide to the Paranasal Sinuses of Domestic Animals

*Mohamed A.M. Alsafy, Samir A.A. El-Gendy
and Catrin Sian Rutland*

Abstract

Paranasal sinuses are paired cavities within the skull, which develop by evagination into the spongy bone between the external and internal plates of the cranial and facial bones. Thus, each sinus is lined by respiratory epithelium and has direct or indirect communication to the nasal cavity. The purpose of this chapter is to present an anatomical reference guide of the paranasal sinuses in domestic animals, including large and small ruminants (cattle, buffalo, sheep, and goats), camels, canines (dog) and equines (horse and donkey), appropriate for use by anatomists, radiologists, clinicians, and veterinary students. Topographic descriptions and the relationships between the various air cavities and paranasal sinuses have been visualized using computed tomography and cadaver sections images. The anatomical features (including head bones, muscles, and soft tissues) have been compared using both dissected heads and skulls and computed tomography images. This chapter will therefore be useful as a normal reference guide for clinical applications.

Keywords: paranasal sinuses, morphology, computed tomography, domestic animals

1. Introduction

The paranasal sinuses develop via evagination into the spongy bone between the external and internal plates of the cranial and facial bones [1]. Therefore, the lining of each sinus comprises of respiratory epithelium. With the exception of the lacrimal and palatine sinuses which are diverticula of the maxillary sinus, each sinus has a direct opening into the nasal cavity. One of the largest problems with sinuses is inflammation, which can be caused by numerous problems including infection and structural abnormalities, and in itself can cause pain and increased infections. Unfortunately, when inflammation occurs, the mucous membrane swells and closes the aperture, this blocks normal sinus drainage [1]. This condition may require surgical drainage. The extensive sinus system possesses considerable clinical interest, especially as it is susceptible to infection that may spread from the nose or from an alveolar abscess [2, 3]. The paranasal sinuses of sheep include the frontal, maxillary, ethmoidal, lacrimal and palatine sinuses. Ovine sinuses differ slightly to cattle, including buffalo, which have frontal, maxillary, sphenoidal, ethmoidal, lacrimal and palatine sinuses [3–5]. Camels are somewhat similar to cattle with frontal, maxillary, sphenoidal, ethmoidal, and lacrimal sinuses [6] with an additional

palatine sinus [7–9]. However, in equids, three paranasal sinuses have been recorded: the frontal, maxillary and sphenopalatine [10–12]. Computed tomography of equine, ruminant and camel heads has enabled production of detailed cross-sectional images of structures and cavities such as the brain case, paranasal sinuses and nasal cavity whilst ensuring that other anatomical structures are not superimposed [4, 6, 11, 12].

2. The paranasal sinuses

2.1 The frontal sinus

The frontal sinus is an air-filled space which occupies the two cortical layers of the frontal bone, the dorsal part of the skull, medial and dorsal to the orbital cavity. It superimposes both the cranial and nasal cavities. The sinus divides into left and right sinuses using a complete median bony interfrontal septum.

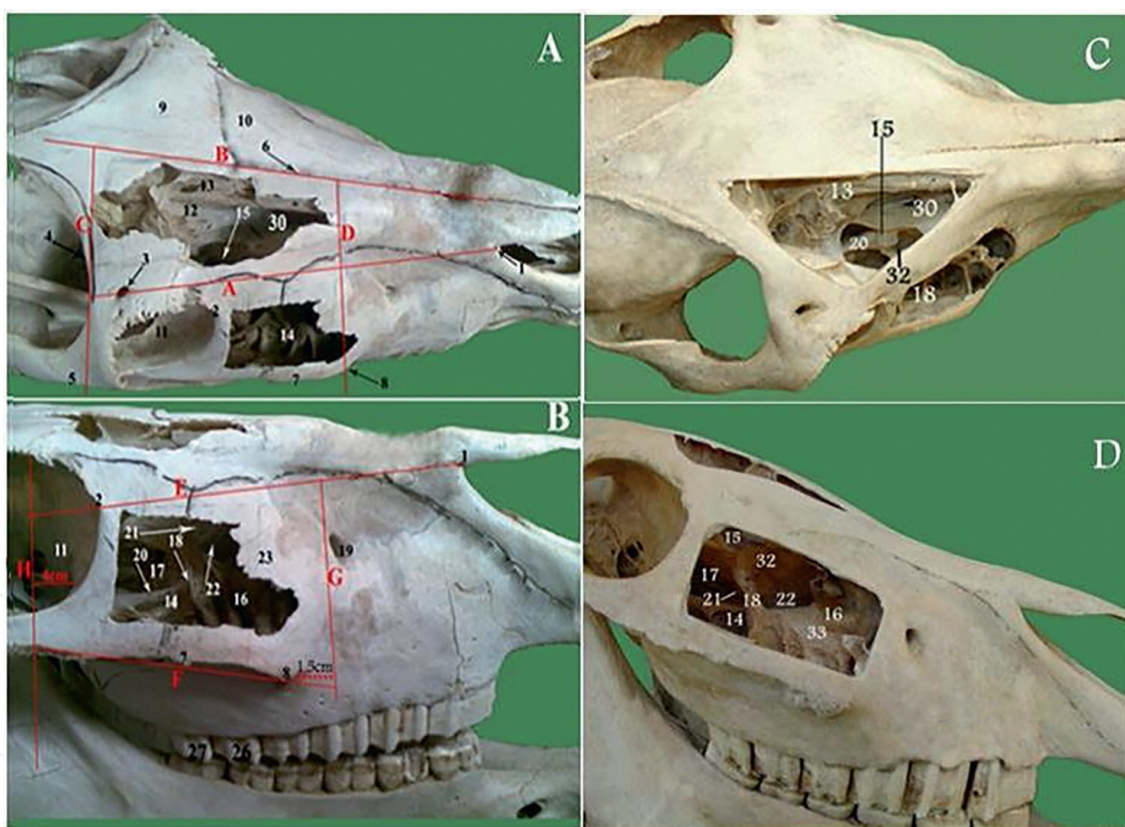


Figure 1.

Topography of frontal and maxillary sinuses in the donkey skull. 1. Nasoincisive notch. 2. Medial angle of the eye. 3. Supraorbital foramen. 4. Caudal border of supraorbital process. 5. Zygomatic arch. 6. Midline of skull. 7. Facial crest. 8. The end of facial crest. 9. Frontal bone. 10. Nasal bone. 11. Orbit. 12. Frontal sinus. 13. Frontal septum between right and left frontal sinuses. 14. Lateral compartment of caudal maxillary sinus. 15. Frontomaxillary opening. 16. Rostral maxillary sinus. 17. Medial compartment of caudal maxillary sinus. 18. Maxillary septum between rostral and caudal maxillary sinuses. 19. Infraorbital foramen. 20. Infraorbital canal. 21. Nasomaxillary opening. 22. Conchomaxillary opening. 23. Maxillary bone. 24. Dotted line indicated the caudal approach line of conchofrontal sinus. 25. Dotted line indicated the rostral approach line of conchofrontal sinus. 26. 2nd maxillary molar tooth. 27. 3rd maxillary molar tooth. 28. Site of approach of caudal maxillary sinus. 29. Site of approach of rostral maxillary sinus. 30. Dorsal Conchal sinus. 31. The lateral segment connected the lateral extent of the caudal and rostral lines. 32. Bulla of ventral nasal Conchal sinus (opened). 33. Bony plate. A, B) 5 year old donkeys, C&D) 12 year old donkeys. Reproduced with permission [13] journal of veterinary anatomy.

In the horse and donkey (**Figures 1-3**), the frontal sinus lies close to the dorsal nasal concha that forms the conchofrontal sinus in horse and donkey (**Figure 1**). The interior of the sinus cavity is incompletely divided by several bony spicules [11]. There is a convexity which exists on the floor of the frontal sinus due to the presence of the underlying ethmoidal labyrinth (**Figures 1 and 3**). It communicates directly with the caudal maxillary sinus by a large oval frontomaxillary opening, there is no frontomaxillary opening in any other domestic animal except in equines [1]. This opening is at the level of the caudal third of second molar tooth and extends caudally by 2–3 cm to the last molar tooth on the lateral floor of the conchofrontal sinus (**Figure 1**, see label 15) [11, 13].

In cattle and buffalo, the frontal sinus extends rostrally to the level of the middle of the third molar tooth at the level of rostral half of orbital rim, which is represented by the nasofrontal suture in the macerated skull. The caudal boundary of the sinus is the nuchal line of occipital bone. The sinus extends laterally to the medial boundary of the orbital rim and temporal line. In turn the cranial cavity bulges into the central

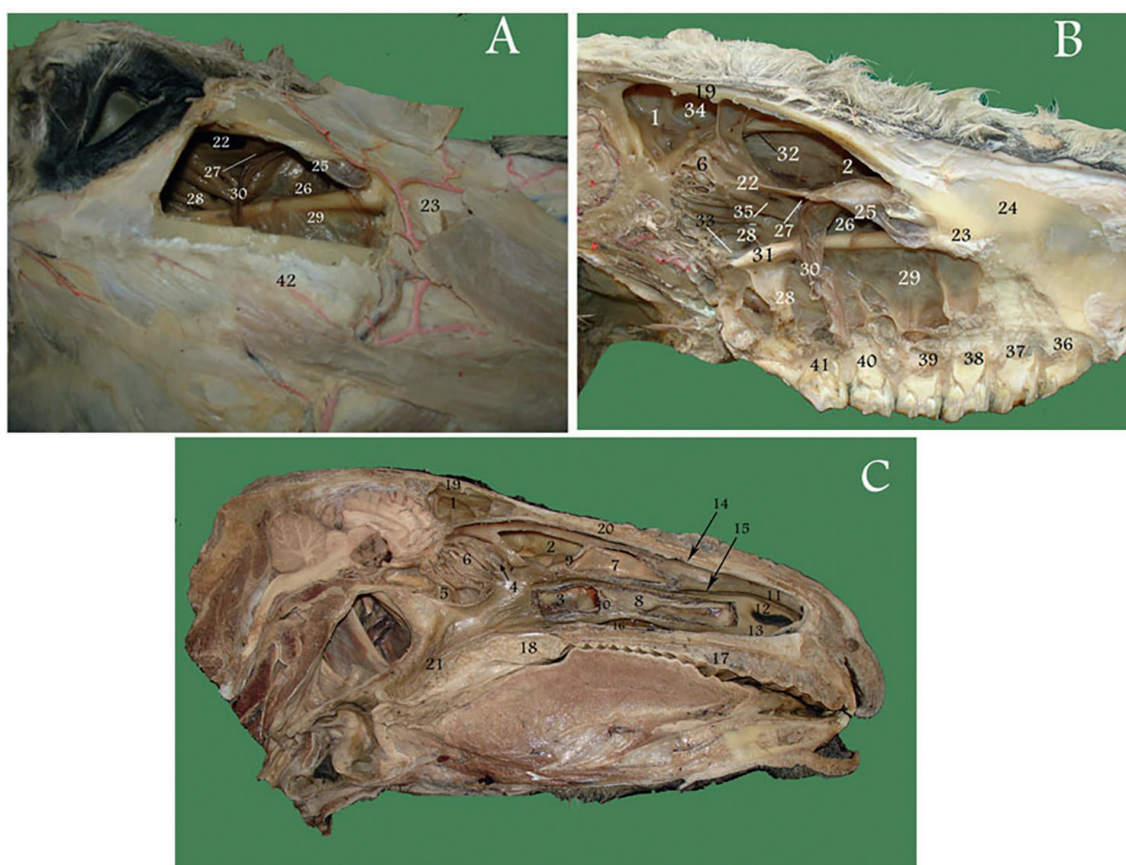


Figure 2. Sagittal sections of the donkey head. 1. Frontal sinus. 2. Dorsal Conchal sinus. 3. Ventral Conchal sinus. 4. Middle Conchal sinus. 5. Sphenopalatine sinus. 6. Ethmoidal turbinate. 7. Bulla of the dorsal nasal concha. 8. Bulla of the ventral nasal concha. 9. Septum of ventral nasal concha. 10. Septum of dorsal nasal concha. 11. Straight fold. 12. Alar fold. 13. Basal fold. 14. Dorsal nasal meatus. 15. Middle nasal meatus. 16. Ventral nasal meatus. 17. Hard palate. 18. Soft palate. 19. Frontal bone. 20. Nasal bone. 21. Pharynx. 22. Frontomaxillary opening. 23. Infraorbital nerve. 24. Maxillary bone. 25. Bulla of ventral nasal Conchal sinus. 26. Conchomaxillary opening. 27. Nasomaxillary opening. 28. Lateral part of caudal maxillary sinus. 28'. Medial part of caudal maxillary sinus. 29. Rostral maxillary sinus. 30. Maxillary septum. 31. Infraorbital canal. 32. Nasolacrimal duct. 33. Sphenopalatine opening. 34. Frontal septum. 35. Opening of middle nasal Conchal sinus into caudal maxillary sinus. 36. 1st maxillary premolar tooth; 37. Second maxillary premolar. 38. 3rd maxillary premolar. 39. 1st maxillary molar tooth. 40. 2nd maxillary molar tooth. 41. 3rd maxillary molar tooth. 42. Facial crest. Reproduced with permission [13] journal of veterinary anatomy.

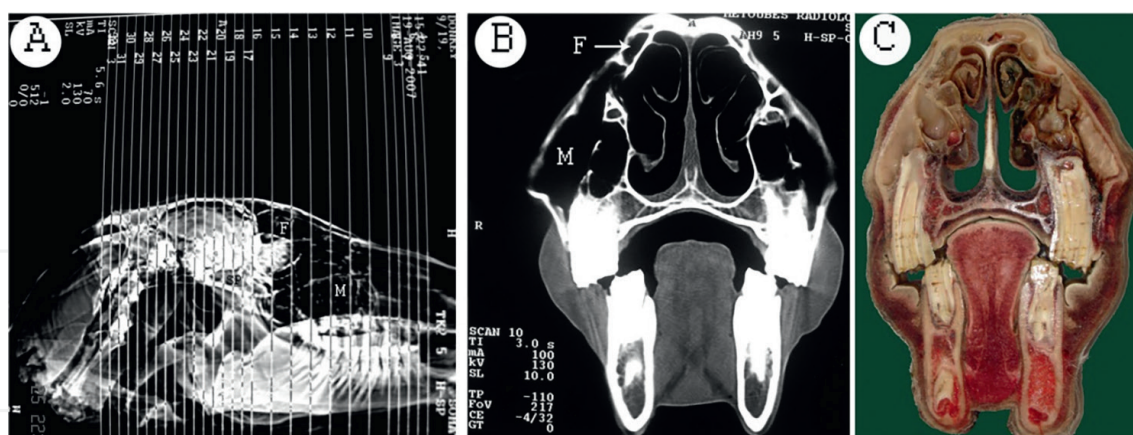


Figure 3. Sinus anatomy in the donkey. (A) Lateral CT scan shows the levels of the section and paranasal sinus. (B) CT at the level of the second cheek tooth maxillary sinus and frontal sinus. (C) Cross section at head) showing the frontal sinus (F). Maxillary sinus (M). Sphenopalatine sinus (SP). Adapted with permission [11].

part of the frontal sinus. The sinus cavity is subdivided into several compartments; these vary in size and differ in position between differing animals and also from left and right sinus [4]. The frontal sinus cavity is divided by an oblique transverse septum creating the rostral and caudal sinuses. The rostral sinus is subdivided into several small lateral, medial and intermediate compartments by the presence of two irregular oblique longitudinal and transverse septa. The rostral sinus compartments all communicate separately with the ethmoidal meatus and rostrally with the dorsal nasal sinus via a nasofrontal opening [4]. One part of the dorsal nasal concha projects caudally between the medial and intermediate rostral sinuses, in addition the lateral rostral sinus is separated by a thin septum from the lacrimal sinus. The caudal sinus is subdivided into the large caudolateral and small rostromedial sinuses by an incomplete oblique transverse septum, the two latter are also able to communicate with each other. An oblique frontal transverse septum divides the caudolateral sinus into two sub-compartments, of which the caudolateral part is separated from nuchal diverticulum by an oblique transverse septum. The caudolateral sinus cavity has three diverticula: the nuchal, cornual and postorbital diverticula. The nuchal diverticulum is more extensive due to the well-developed parietal bone, and is itself subdivided into four sub-compartments. The cornual diverticulum extends into the cornual process of the frontal bone, and is subdivided by a septum [2]. The postorbital diverticulum is located medially, caudal to the orbital cavity, and dorsal to the cranial cavity, and occupies the space between the orbital cavity and rostral frontal small compartments. The relatively short supraorbital canal passes through the lateral border of the caudal frontal sinus through an apparently bony septum. The caudal frontal sinus opens up in the ethmoidal meatus (**Figures 4-6**).

In the camel, each frontal sinus is subdivided by bony plates into six large compartments; two caudal, two lateral and two rostral, surrounding eight small compartments that communicate with the nasal fundus through small openings. The supraorbital canal is traverse to the large caudolateral compartment where the supraorbital foramen is present (**Figure 7**) [6].

In sheep and goats, each frontal sinus is subdivided into interconnected lateral and medial chambers, differing in size, by many bony plates. The medial chamber has only one elongated chamber, which contains no bony plates, communicating only with the middle part of the lateral chamber. Meanwhile the lateral chamber has three portions rostral, middle and caudal, and three diverticula nuchal, cornual and orbital [14]. The

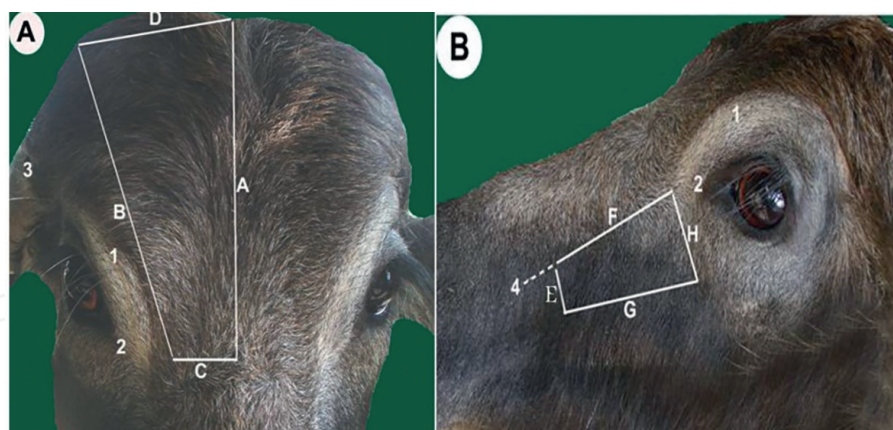


Figure 4.
 Topography of the frontal and maxillary sinuses of the buffalo head (a& B). 1. Supraorbital foramen. 2. Medial angle of the eye. 3. Cornual process. 4. Infraorbital foramen. A. Medial limit of frontal sinus (Medline of the head). B. Lateral limit of frontal sinus. C. Rostral limit of frontal sinus. D. Caudal limit of frontal sinus. E. Rostral limit of maxillary sinus. F. Dorsal limit of maxillary sinus. G. Ventral limit of maxillary sinus. H. Caudal limit of maxillary sinus.

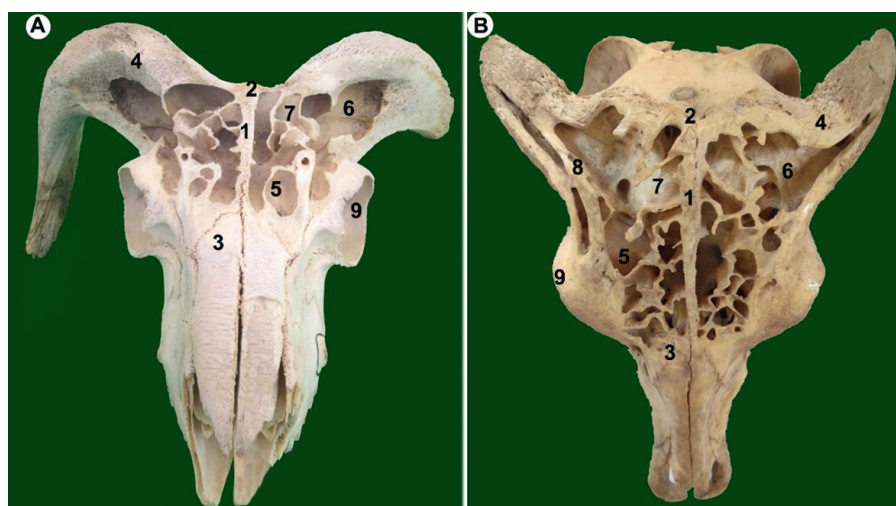


Figure 5.
 Frontal surface of sheep (a) and buffalo (B) skulls showing the frontal sinuses. 1. Median interfrontal septum. 2. Parietal bone. 3. Nasal bone. 4. Cornual process of the frontal bone. 5. Postorbital diverticulum of the frontal sinus. 6. Cornual diverticulum of the frontal sinus. 7. Nuchal diverticulum of the frontal sinus. 8. Cornual septum. 9. Orbital cavity.

dorsal part of the lateral chamber communicates with the dorsal conchal sinus, the middle part communicates with the medial chamber and its caudal part communicates with the three frontal diverticula. The cornual diverticulum is the largest diverticula and is itself divided into a small dorsal part and a large ventral part by an oblique transverse septum [14]. The orbital diverticulum is surrounded by the orbital cavity dorsally and caudally, however, the nuchal diverticulum is the smallest one. The supraorbital canal meanwhile is a short canal, located at the longitudinal interfrontal septum between the lateral chamber and orbital diverticulum of each frontal sinus (**Figure 5**).

In the dog and cat, the paired frontal sinuses have open communication with the nasal cavity. The rostral frontal sinus lies between the median osseous septum of the frontal sinus and the orbit. The lateral frontal sinus is the largest of the frontal sinuses and extends into the zygomatic process of the frontal bone. The medial frontal sinus is very small and lies between the other two, occasionally it is absent.

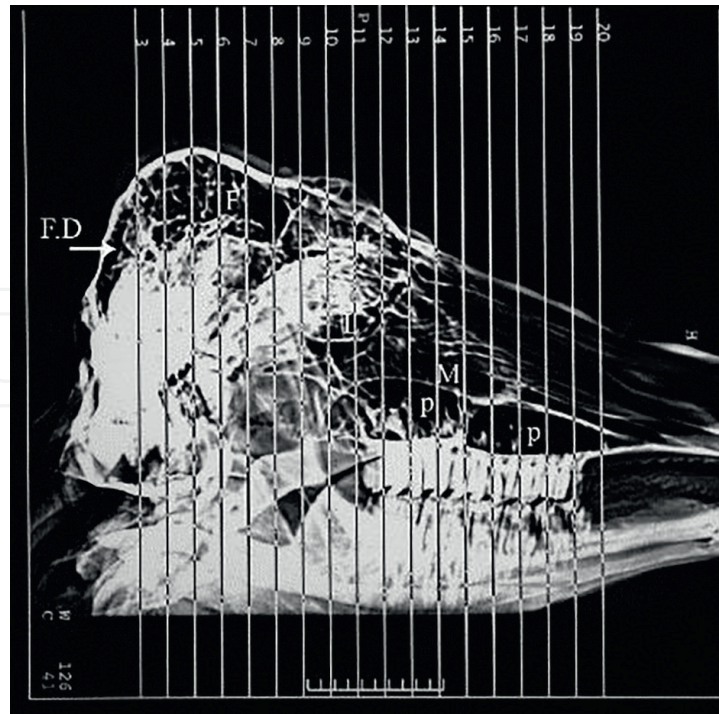


Figure 6. Lateral CT scan shows the levels of the section and paranasal sinus in the buffalo. F. frontal sinus. C.D. Cornual diverticulum of frontal sinus. P. Palatine sinus. M. Maxillary sinus. L. Lacrimal sinus.

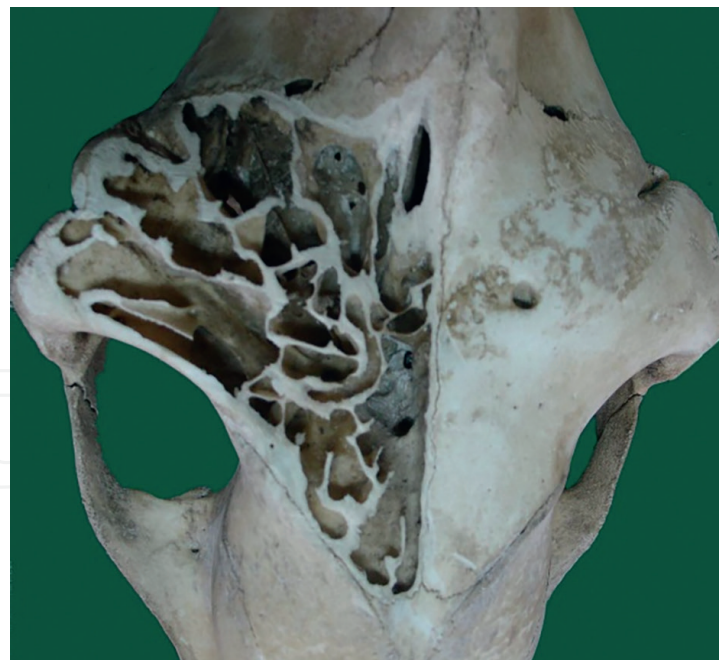


Figure 7. Frontal surface of the camel skull showing the frontal sinuses.

2.2 The maxillary sinus

In the horse and donkey, the maxillary sinus divides into rostral and caudal compartments via a thin incomplete bony septum in the donkey or a complete septum in horse. The dorsal part of the septum was designed by the bulla of the ventral conchal

sinus. This septum angles obliquely caudally and its rostral aspect is varied in with regards to location; it usually crosses the roots of the second and third molar teeth, approximately 4–5 cm caudal to the rostral end of the facial crest. Most specimens have a septum measuring around 1.5 cm high, whilst the sinus can be 4–5 cm deep with bony spicules [11]. The caudal maxillary sinus is incompletely divided by the infraorbital canal into lateral and medial compartments. The canal also facilitates free communication between the two parts. Only the third maxillary molar tooth root embeds in the caudal maxillary sinus. The rostral and caudal maxillary sinuses connect with the middle nasal meatus via a slit-like nasomaxillary opening. The capacious caudal maxillary sinus appears larger than the smaller rostral maxillary sinus. The rostral maxillary sinus communicates with the ventral conchal sinus via the wide conchomaxillary opening dorsal to the infraorbital canal. The opening of which located at the level of the rostral part of the first molar tooth until the caudal part of the second molar tooth. The rostral maxillary sinus is around 4–5 cm long and 0.3–0.4 cm wide (**Figures 1–3**) [11, 13]. When CT imaged, the maxillary sinus is low in density but has high-density structures; the infraorbital canal, maxillary septum and bony spicules.

In cattle and buffalo, the maxillary sinus excavates into the maxillary and lacrimal bones. The sinus cavity is triangular in shape as the base is located caudally with a cranial apex behind the infraorbital foramen. The cavity extends rostrally towards the facial tuberosity at the level of the caudal border of the second premolar tooth. Around 2–3 cm ventral to the orbit and caudal to third molar tooth, the sinus continues caudally into the lacrimal bulla which has thinner walls and the zygomatic bone [4]. The dorsal limit of the cavity is determined by a line extending from the infraorbital foramen to the medial canthus of eye, while the ventral limit is around 1–2 cm above the alveolar border. Under computed tomography imaging, the more dense infraorbital canal and bony spicules of the maxillary sinus are observed. The maxillary sinus communicates with the caudal part of middle nasal meatus in common with the palatine sinuses through the nasomaxillary opening. This opening is positioned on the medial wall just ventral to the nasolacrimal canal, over the infraorbital canal and at around the midpoint between the orbit and facial tuber at a level from the first molar to third molar teeth. The maxillary and palatine sinuses communicate through an oval maxillopalatine opening, located above the infraorbital opening at a level from second premolar to the second molar teeth [4]. Caudally, it also communicates with the lacrimal sinus through maxillolacrimal opening. There is a rostral crest within the maxillary sinus (**Figure 4**).

In camels, the maxillary sinus is in an excavation of a small part of the maxillary bone and the rostral part of the zygomatic bone. The maxillary sinus extends towards the level of the rostral border of the third upper cheek tooth. The medial boundary is formed by the osseous nasolacrimal canal and it communicates dorsally with the lacrimal sinus and with the caudal part of the middle nasal meatus via the nasomaxillary opening which in turn is partly covered by the lateral part of the dorsal conchal sinus [6].

In sheep and goats, the maxillary sinus is located in a triangular excavation of the maxillary bone and rostral part of the zygomatic bone. The sinus extends to the level of the rostral border of the third upper cheek tooth and rostral to the facial tuberosity. The sinus is incompletely separated by the infraorbital canal, therefore presenting as a smaller dorsomedial part and a larger ventrolateral part, [14]. Caudally, the sinus become larger and extends by the lacrimal bulla. This lacrimal bulla presents as dorsal and ventral orbital diverticula inside the orbital cavity. The sinus communicates dorsally with the lacrimal sinus by the maxillolacrimal opening, whilst the caudal section of the sinus communicates with the palatine sinus via the maxillopalatine opening on the medial side of the infraorbital canal. In addition, the sinus communicates with

the caudal part of the middle nasal meatus via the nasomaxillary opening which is partially covered by the lateral part of the dorsal nasal conchal sinus at the level of the fourth cheek tooth (**Figure 5**) [14].

In the dog and cat, in contrast to the other domestic mammals, the canine maxilla has no paranasal sinus, but rather a laterally directed outpouching, the maxillary recess.

2.3 The sphenoidal sinus

In the horse and donkey, the sphenoidal and palatine sinuses communicate with each other. The sphenopalatine sinuses are excavated into the palatine and sphenoid bones ventromedial to the orbit and ventral to forebrain [11]. There is a septum separating the left and right sphenoidal sinuses, however, it is not frequently in the midline. The dorsal and lateral walls of the sphenopalatine sinus are thin. The sinus communicates with the caudal maxillary sinus via the sphenopalatine opening, which is the most caudal opening of the maxillary sinus. The opening itself appears sagittal oblique and is located between the caudal origin of the infraorbital canal and the pterygopalatine fossa, caudal to the last molar tooth roots (**Figure 2** structures 5 and 33 [13]).

In cattle and buffalo, the sphenoid sinus is shallow and excavated in the body and wing of the sphenoid bone [4]. The right and left sinuses are divided by a septum forming unequal small parts, the rostral canal and caudal cavity. It opens into the ethmoidal meatus via the nasosphenoidal opening.

In camels, the sphenoidal sinus is in a cavity within the body and wing of the sphenoidal bone. The sinus contains bony plates which subdivide it into small compartments, which alongside the frontal sinus compartments encircle the cranial cavity [6]. The sphenoidal sinus opens directly into the nasal fundus through the nasosphenoidal opening [6].

In the dog and cat, in some cases a sphenoidal sinus develops but not always.

2.4 The ethmoidal sinus

In cattle and buffalo, the ethmoidal cells are small cavities in the medial wall of the orbit [4]. The ethmoid bone forms the medial wall whereas their lateral walls are formed by the frontal, palatine and the wing of presphenoid bones. The ethmoidal cells open into the ethmoidal meatus.

In camels, the ethmoidal sinus is apparent in the ethmoid labyrinths. It communicates directly with the ethmoidal meatus into the nasal fundus [6].

In sheep and goats, the ethmoidal sinus is located at the nasal fundus part of the nasal cavity [14]. The ethmoidal sinus is apparent in the five triangular projections of the ethmoidal labyrinths. It communicates directly with the ethmoidal meatus into the nasal fundus.

2.5 The lacrimal sinus

In cattle and buffalo, the lacrimal sinus is a small excavation in the lacrimal and frontal bones rostromedial to the orbit. The lacrimal bones forms the lateral wall and the lateral mass of the ethmoidal bone forms the medial wall. The sinus cavity is not divided by osseous plates and the nasolacrimal canal traverses its lateral wall. It communicates with the maxillary sinus via maxillo-lacrimal opening (**Figures 5 and 6**).

In camels, the lacrimal sinus occupies a small cavity in the lacrimal bone rostromedial to the orbit. The lacrimal bone forms the lateral wall, while the lateral mass of

	Horse and donkey	Cattle/buffalo	Sheep and goat	Camel	Dog
Maxillary	+	+	+	+	Recess
Frontal	+	+	+	+	+
Lacrimal	—	+	+	+	—
Palatine	—	+	+	+	—
Sphenoid	—	+	—	—	—
Sphenopalatine	+	—	—	—	—

+ Present. -Absent.

Table 1.
The paranasal sinuses in a range of mammals.

the ethmoidal bone forms the medial wall. The lacrimal sinus is separated rostrally from the maxillary sinus by the nasolacrimal canal and it communicates with the maxillary sinus via the maxillo-lacrimal opening, just anterior to the orbital cavity at the level of third cheek tooth [6].

In sheep and goats, the lacrimal sinus occupies a small cavity in the lacrimal bone rostromedial to the orbit. The lateral wall is formed by the lacrimal bone, while the medial wall is formed by the lateral border of the dorsal lamellae of the ventral nasal conchae [14]. It is separated rostrally from the maxillary sinus by the nasolacrimal canal and communicates with the maxillary sinus via the maxillo-lacrimal opening just anterior to the orbital cavity at the level of the third cheek tooth (**Figure 5**).

2.6 The palatine sinus

In cattle and buffalo, the palatine sinus appears larger than the maxillary sinus and is located within the horizontal part of the palatine bone and the palatine process of maxillary bone. The right and left palatine sinuses are separated by a median interpalatine septum, which is undulant caudally. The sinus extends from the caudal border of the palatine bone and rostral border of the orbit roughly 2 cm caudal to the third molar tooth to around 3–4 cm rostral to the first premolar teeth [4]. The sinus cavity contains an incomplete transverse bony crest which arises from the floor of sinus and subdivides the sinus into two unequal compartments. The caudal part of the sinus is traversed obliquely by the infraorbital canal that divides it into medial and lateral compartments. The palatine sinus communicates with the maxillary sinus via a maxillopalatine opening over the infraorbital canal (**Figure 6**).

In sheep and goats, the palatine sinuses are located within the horizontal part of the palatine bone and the palatine process of the maxillary bone, and it is the smallest sinus. The right and left palatine sinuses are separated by a median inter-palatine septum [14]. The sinus extends from the caudal border of the palatine bone and rostral border of the orbit caudal to the third molar tooth. The palatine sinus communicates with the maxillary sinus by the maxillopalatine opening over the infraorbital canal (**Table 1**) [3].

Conflict of interest

The authors declare no conflict of interest.

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