SVU- International Journal of Veterinary Sciences, 4 (3): 80-93, 2021.
Print ISSN: 2535-1826 **Online ISSN: 2535-1877**

Research Article Open Access

Gross anatomical and morphometrical study of the nasal cavity (cavum nasi) of Egyptian goat (Capra hircus) and Egyptian Baladi dog (Canis lupus)

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Abstract

This study aims to provide enough information on the anatomical investigation and the morphometrical analysis of the nasal cavity of Egyptian goat and Egyptian Baladi dog. The sagittal and the cross (transverse) sections at the different levels were performed on twenty heads of those animals. The nasal cavity was typically cone-shaped in goat and a slight narrow elongated cone-shaped in dog. It was completely divided by the nasal septum in both species except the caudal part of the nasal cavity of goat was partially divided. The nostril of the goat was nearly horizontal slit-like in form, directed ventromedially toward the philtrum. Whereas, the nostril of the dog was somewhat comma-shaped with its wide part directed medially toward the nasal septum. In the sagittal section, the nasal conchae were included in goat and dog; the dorsal nasal concha, the ventral nasal concha, the middle nasal concha and the ethmoidal conchae. The dorsal nasal concha was the longest concha in both animals. In the cross section, the dorsal nasal concha in goat was formed the dorsal conchal sinus at the level of the third premolar teeth and extended caudally into the frontal sinus. The ventral nasal concha didn't form sinus but its spiral lamellae enclosing the recesses. Moreover, the middle conchal sinus was appeared at the level of the first molar teeth. In this section, all the nasal conchae of dog were formed recesses (conchal sinuses absent). The caudal blind end of the vomeronasal organ was observed at the level of the third premolar teeth in goat and the first premolar teeth in dog.

Keywords:
Concha, Dog, Goat, Nasal cavity, Sinus.

DOI: 10.21608/svu.2021.86098.1134 Received: July 13, 2021 Accepted: August 25, 2021 Published: September 11, 2021

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Citation: Madkour and Abdelsabour-Khalaf, Gross anatomical and morphometrical study of the nasal cavity (cavum nasi) of Egyptian goat (Capra hircus) and Egyptian Baladi dog (Canis lupus). SVU-IJVS 2021, 4 (3): 80-93.

Competing interest: The authors have declared that no competing interest exists.

Introduction

The study of the respiratory system is important especially for the animals which migrate continuously as goat and sheep from the low hills to the high Alpine pastures (Pathak & Rajput, 2015). The economic loss of the animal industry usually occurs as result of the respiratory diseases, where the major site of the infection from the respiratory system is the nasal cavity (Hillmann, 1971). So, the anatomist should be interested in the study of the respiratory system especially the nasal cavity.

In the domestic animals, the nasal cavity extends from the nostrils externally to open into the nasopharynx through the caudal nares (Nickel et al., 1979). In animals, the skin between the nostrils and around them presents certain peculiarities. It is either smooth and hairless, or granular and marked by grooves. It may contain gland and presents fine ordinary and tactile hairs (El-hagri, 1967).

The nasal cavity is divided by the nasal septum into the right and left nasal cavities and occupies a large part of the face and extends caudally up to the transverse bony septum at the rostral end of the cranial cavity (Dyce et al., 2018). Moreover, this cavity is concave from side to side and almost straight longitudinally, except in the caudal part where it curves ventrally (El-hagri, 1967). The caudal part of the nasal cavity is responsible for the olfaction. Nickel et al. (1979) documented that the olfactory region at the nasal cavity registers the presence of harmful substances in the air and triggers a reflex that closes the air passage in the larynx.

Within the nasal cavity the most interesting structures observed are the dorsal, middle, ventral and ethmoidal conchae; each concha is a thin delicate scroll like bone covered by respiratory epithelium (El-hagri, 1967; Nickel et al., 1979; Hare, 1975). These conchae increase the surface area of the respiratory epithelium of the nasal cavity.

Several authors interested in the study of the respiratory system of the different animal species, especially the nasal cavity (Hillmann, 1971; Abdel-Aziz, 1983; Hamoda, 2000; Pathak & Rajput, 2015; Metwally et al., 2019; Elsaid et al., 2020). Even the nasal cavity of the different species of the birds are attested by several researchers (Ali, 2015; Casteleyn et al., 2018; Madkour, 2019; Dharani et al., 2020; Hanafy, 2021). Basing on the latter authors, we provide here certain detailed information regarding the gross anatomical investigations of the nasal cavity of the small animals (Egyptian goat and Egyptian Baladi dog) to availability much details of the respiratory system.

Materials and methods

This study was carried out on two different species of animals (adult age); Egyptian goat (Capra hircus) and Egyptian Baladi dog (Canis lupus). The heads of the Egyptian goat (n=10) of both sexes were immediately collected after sacrificing from the automatic abattoir in Qena Governorate, Egypt. Egyptian Baladi dog (n=10) of both sexes were procured by the local hunters in Qena Governorate. The heads of those animals were separated after euthanizing by intravenous injection of thiopental sodium at the Department of Anatomy and Embryology, Faculty of Veterinary Medicine, South Valley University. The collected heads of both animals were

carefully washed with distilled water then fixed in 10% neutral buffer formalin (NBF).

The heads of both species were cut at two sections; cross (transverse) and sagittal sections using the electrical sawing machine (Germany). The cross (transverse) sections were performed on five heads of each species at the different levels of the heads; at the level of the canine teeth (dog), the rostral third of the dental pad (goat), at the level of the caudal margin of the first premolar, the third premolar and the first molar teeth for both animals (Fig. 1a & b). The sagittal sections were carried out on five heads of each species. The examined features of the nasal cavity were photographed using phone camera (I Phone 4S).

We converted the current figures to the negative images to more clarify the detailed structure by using CMEIAS Color Segmentation, improved computing technology. The steps of this process, firstly, open image with CMEIAS Color Segmentation, then edit "Process" from the menu items and choose "Negative image" (Gross et al., 2010). Several authors previously used this method (Madkour et al., 2021).

The different measurements of the nasal cavity and its structures were taken for each head separately using a digital vernier caliper (Vogel, Kevelaer, 8 Germany). All data were statistically analyzed by the Statistical Package for Social Science (SPSS) software program and expressed as mean and standard error (SE). The terminology used in this study was in accordance with Nomina Anatomica Veterinaria (2006).

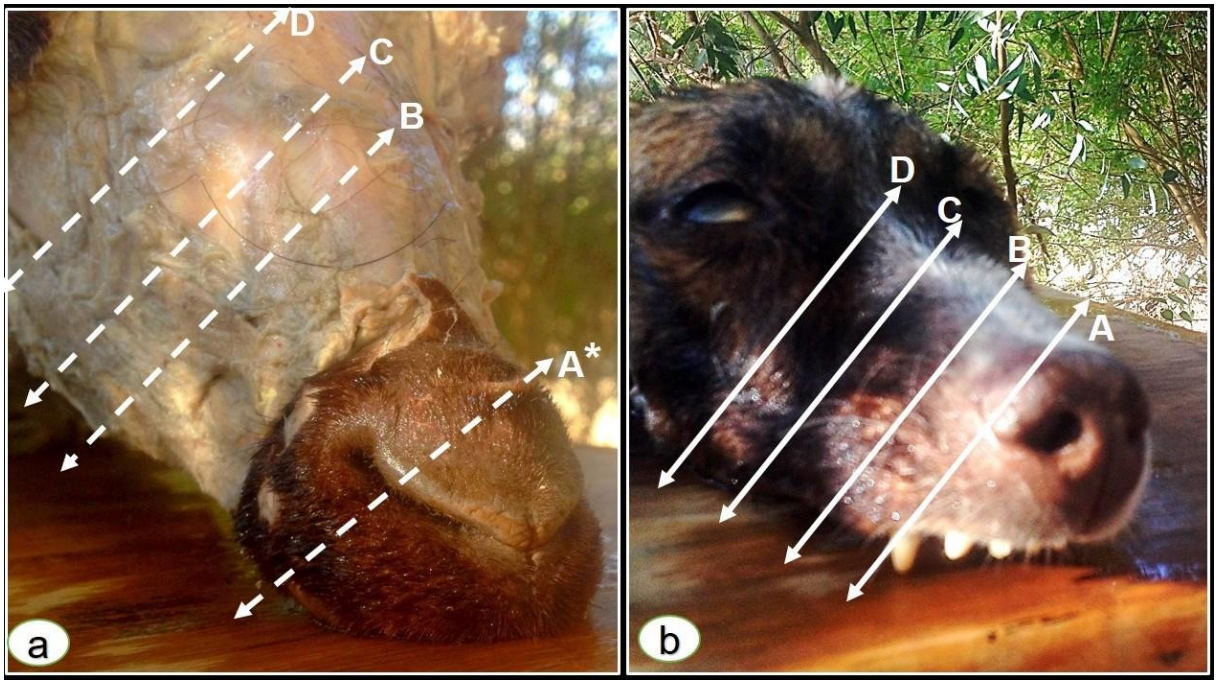

Fig. 1. Photographs of the head (a) of goat, (b) of dog showing three planes of the cross sections at the different levels. Note, plane (A) at the level of the canine teeth (dog), (A*) at the rostral third of the dental pad (goat), (B) at the level of the caudal margin of the first premolar teeth, (C) at the level of the caudal margin of the third premolar teeth, and (D) at the level of the caudal margin of the first molar teeth.

Ethical approval

The animal ethical committee of the Faculty of Veterinary Medicine, SVU, Egypt, approved the collection and handling of this study. These methods were performed following the guidelines of the institutional ethical committee of SVU, Egypt.

Results

The nasal cavity (cavum nasi) was the portion of the upper respiratory system. It was typically cone-shaped in goat and a slight narrow elongated cone-shaped in dog. It was extended rostrally from the rostral nares (nostril) to the caudal nares (choanae) caudally.

The nostril was located at the apex of the nose which was incorporated in the face in goat but protruded to some extent from the face in dog. The nostril of goat was nearly horizontal slit-like in form, directed ventromedially toward the philtrum (Fig. 2a & b). It was away from the tip of the upper lip by1.42 ± 0.11 cm. The nostril consisted of two commissures; the rostral commissure was situated by 2.45 ± 0.10 cm from the caudal one and its width was measured 1.17 ± 0.14 cm. Whereas, the nostril of dog was somewhat comma-shaped with its wide part directed medially toward the nasal septum and its narrow part directed laterally (Fig. 2c & d). It was located by 1.66 ± 0.14 cm from the tip of the upper lip. The nostril was 2.1 ± 0.11 cm long (from the wide to the narrow parts) and 1.18 ± 0.13 cm wide (at the widest point).

The dimensions of the area between the two nostrils of goat and dog, which corresponding the nasal septum externally were 0.57 ± 0.9 and 0.82 ± 0.13 cm wide, respectively. The nostrils of both species were surrounded by the modified skin termed the nasal plane (planum nasale). The nasal plane was hairless and marked by fine grooves. Moreover, this planum nasale was divided by the philtrum on the upper lips of these species which was continued dorsally between the two nostrils (Fig 2a-d). This area was the animal health guide.

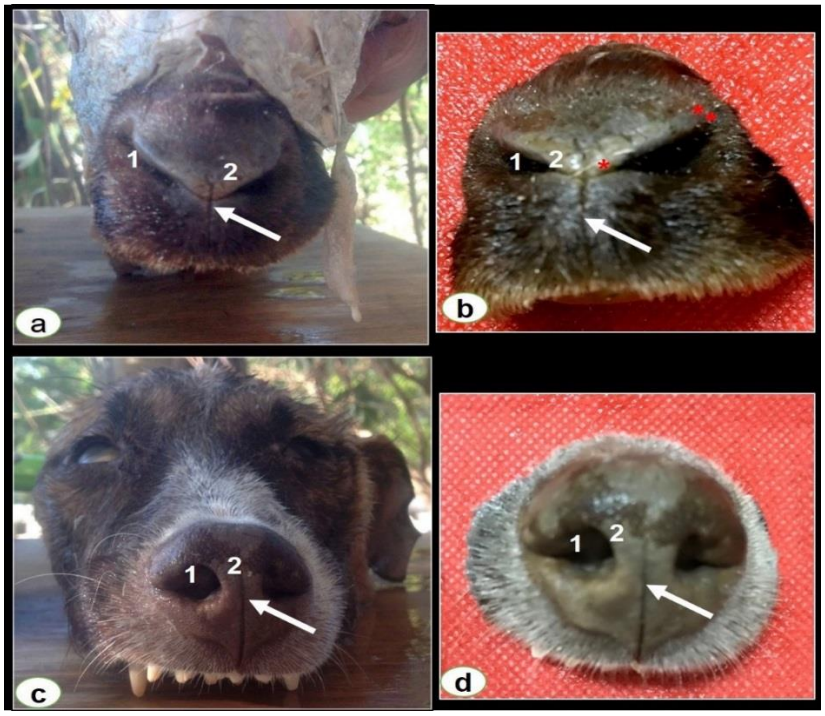

Fig. 2. Photographs of the rostral end of the head (a & b) of goat, (c & d) of dog, showing 1- Nostril consists of rostral commissure (star), caudal commissure (Double stars), 2- Planum nasale, philtrum (arrow).

The divisions of the nasal cavity of both animals were similar to those of the previous studied species. It was divided into two symmetrical halves by the nasal septum. Each half was formed of three parts according to the lining epithelium; rostral part (nasal vestibule), middle part (nasal cavity proper) and caudal part (nasal fundus). The nasal septum (septum nasi) consisted of cartilaginous part rostrally and bony part caudally (Fig. 3a & c).

In the sagittal sections, the nasal cavity was separated from the cranial cavity by the ethmoidal and the nasal part of the frontal bones and it was mostly occupied by the nasal conchae (conchae nasalis). The nasal conchae were included in goat and dog; the dorsal nasal concha, ventral nasal concha, middle nasal concha and ethmoidal conchae. The first three conchae were located within the large middle part of the nasal cavity while the ethmoidal conchae were localized at the caudal portion. The dorsal nasal concha was separated from the roof of the nasal cavity by the dorsal nasal meatus and from the ventral nasal concha by the middle nasal meatus. The latter meatus was split caudally into two channels by the middle nasal concha. The ventral nasal concha was separated from the floor of the nasal cavity by the ventral nasal meatus. Furthermore, the ethmoidal conchae were separated from each other by air spaces (ethmoidal meatuses) (Fig. 3b & d). The dimensions of the nasal meatuses in goat were wider than those in dog except the ventral nasal meatus. The dorsal nasal meatus, middle nasal meatus, ventral nasal meatus were measured 0.54 ± 0.11, 0.54 ± 0.15, 0.31 ± 0.14 cm in goat, and 0.32 ± 0.14, 0.32 ± 0.25, 0.47 ± 0.34 cm in dog, respectively. The dorsal nasal concha in both species was occupied the upper half of the nasal cavity and was long uniform plate-like but slightly wide at the middle in goat (Fig. 3b & d). It was measured 10.53 ± 0.09, 7.25 ± 0.10 cm long and 1.2 ± 0.26, 0.44 ± 0.14 cm wide in goat and dog, respectively. However, the ventral nasal concha was occupied the lowest half of the nasal cavity and it was long, mostly wide and tapered toward either end in goat (Fig. 3b). This concha in dog was occupied the lower rostral half of the nasal cavity and it was extensively folded and was the shortest one. The caudal portion of the ventral nasal concha was arranged in many longitudinal folds which united rostrally to form the alar fold (Fig. 3d). The length and the width of the ventral nasal concha were 9.48 ± 0.10, 2.3 ± 0.54 cm in goat and 4.67 ± 0.35, 0.52 ± 0.43 cm in dog, respectively. Furthermore. The middle nasal concha in goat was located between the posterior third of the dorsal and ventral nasal conchae and within the ethmoidal conchae. It was as V-shaped and considerable the shortest one (Fig. 3b). While in dog, the middle nasal concha was observed between the caudal half of the dorsal nasal concha and the caudal end of the ventral nasal concha. It was wrinkled rostrally and twisted caudally and it was approximately resembled the ventral concha in length (Fig. 3d). The length and the width of the middle nasal concha were 5.13 ± 0.14, 0.4 ± 0.65 cm in goat and 4.74 ± 0.24, 0.57 ± 0.52 cm in dog, respectively. The ethmoidal conchae were smaller, numerous in goat and extended considerably forward in the nasal cavity in dog (Fig. 3b & d). Within the sagittal sections, we observed in both species that the mucosa of the lateral wall of the rostral part of the nasal cavity was formed of number of folds which extended from the

nasal conchae to the rostral nares. The straight fold (plica recta) was the most dorsal of the folds and was continuous with the dorsal nasal concha. The length of this fold was 2.23 ± 0.14 cm in goat, and 2.35 ± 0.9 cm in dog. Ventral to the straight fold was the alar fold (plica alaris) (3.18 ± 0.13 cm long in goat and 2.22 ± 0.12 cm long in dog) which was continuous with the ventral nasal concha. In goat, the rostral end of the alar fold was thick and rounded-shaped united with the ill developed basal fold (plica basalis) which was the most ventral part. While in dog the basal fold was not observed (Fig. 3b & d).

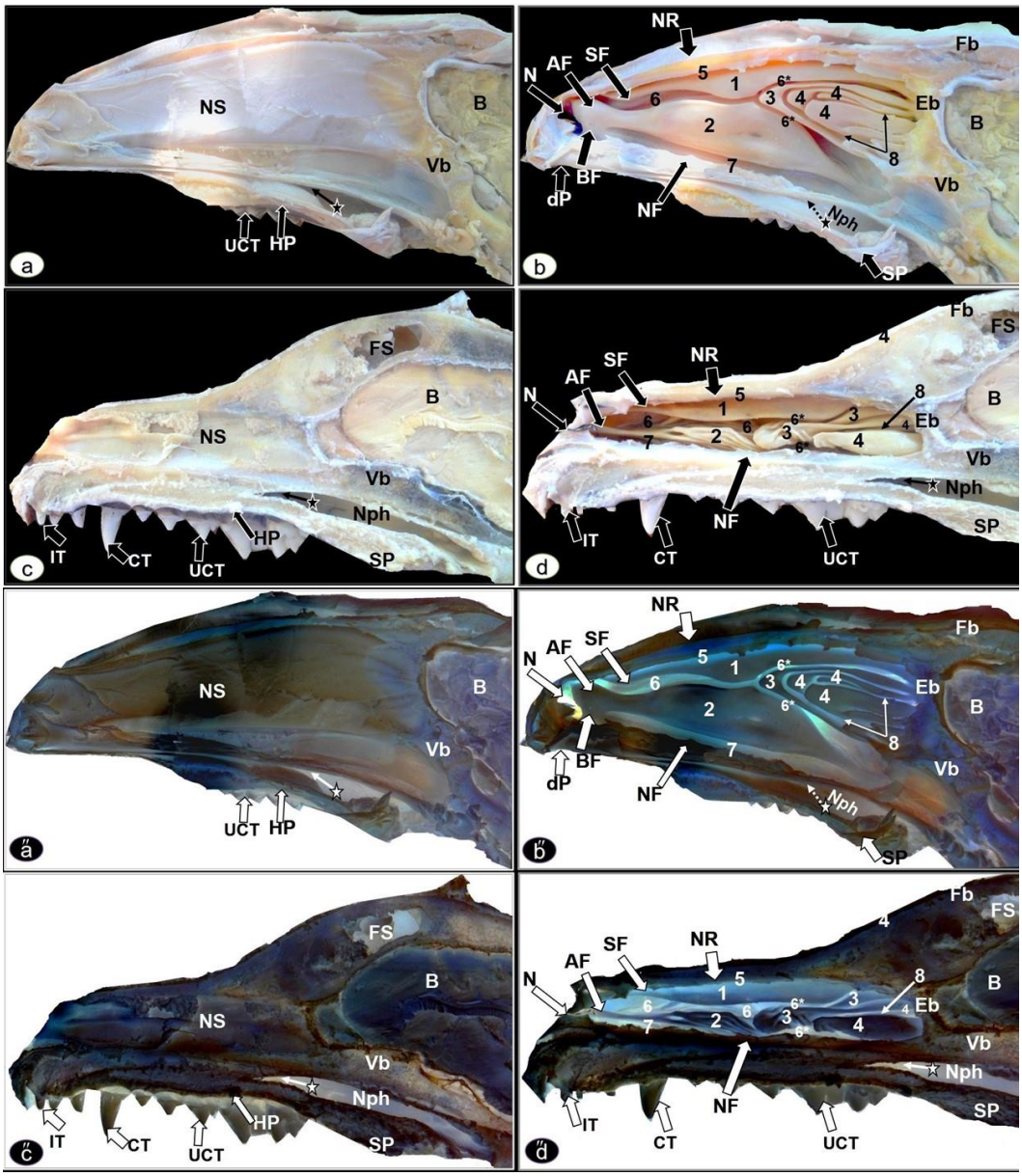

Fig. 3. Photographs of the sagittal section of the nasal cavity (a & b) of goat, (c & d) of dog and (a''- d'') their negative images, showing nasal septum (NS), roof (NR) and floor (NF) of the nasal cavity, nostril (N), straight fold (SF), alar fold (AF), basal fold (BF), dental pad (dp), incisive teeth (IT), canine teeth (CT), upper cheek teeth (UCT), vomer bone (Vb), ethmoidal bone (Eb), frontal bone (Fb), hard plate (HP), soft palate (SP), choana (star), nasopharynx (Nph), frontal sinus (FS), brain (B). (b & d) showing 1-dorsal nasal concha, 2-ventral nasal concha, 3-middle nasal concha, 4-ethmoidal concha, 5-dorsal nasal meatus, 6- middle nasal meatus, 6*- two channels of the middle nasal meatus, 7- ventral nasal meatus, 8- ethmoidal meatus.

In cross (transverse) sections, at the level of the rostral third of the dental pad (goat), and at the level of the canine teeth (dog), the alar fold in goat was elevated dorsally toward the roof of the nasal cavity. While, in dog, it was projected with rounded end mediodorsally as a shelf from the lateral wall of the nasal cavity and was separated from the nasal septum by the common nasal meatus (Fig. 4a & b).

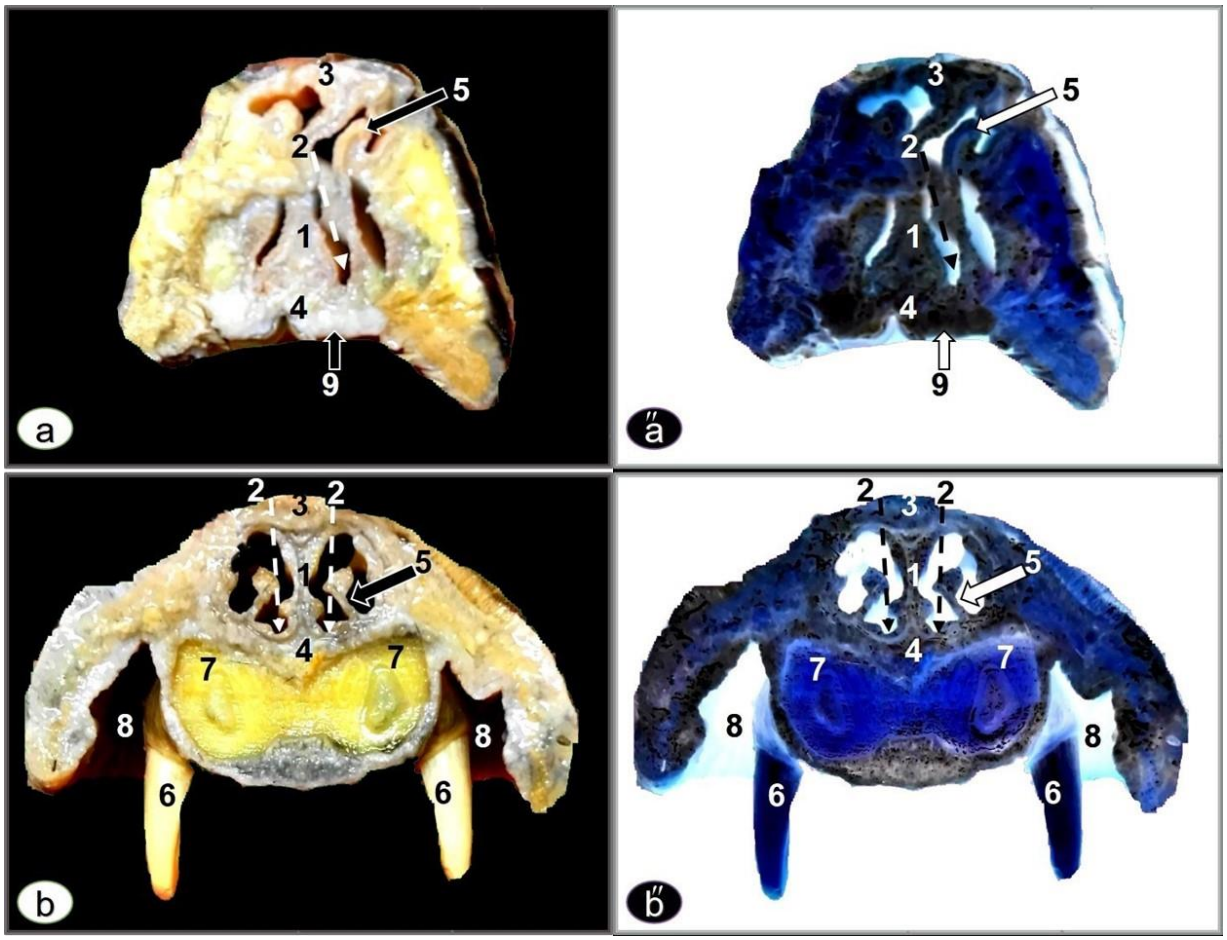

Fig. 4. Photographs of the cross section of the nasal cavity (a) at the level of the rostral third of the dental pad of goat, (b) at the level of canine teeth dog and (a" & b") their negative images, showing 1- nasal septum, 2- common nasal meatus, 3- roof of the nasal cavity, 4- floor of nasal cavity, 5- alar fold, 6-canine teeth, 7-root of canine teeth, 8- buccal vestibule, 9- dental pad.

At the level of the first premolar teeth in both species, the dorsal nasal concha consisted only of the basal lamella and had the appearance of a shelf (Fig. 5a & b). This basal lamella in dog was curved medioventrally toward the ventral nasal concha and the nasal septum. The nasal septum at this level in dog was appeared thinner than that in goat, in addition, the vomeronasal organ (Organumvomero nasale) was observed on each side of the nasal septum (Fig. 5b). On the other hand, the ventral nasal concha in goat consisted of one spiral lamella. The spiral lamella was rolled one and a half turn medially, dorsally, laterally, then medially and enclosed a recess (Fig. 5a). While in dog, the spiral lamella of the ventral concha was divided into several branching secondary lamellae, creating multiple narrow recesses (Fig. 5b).

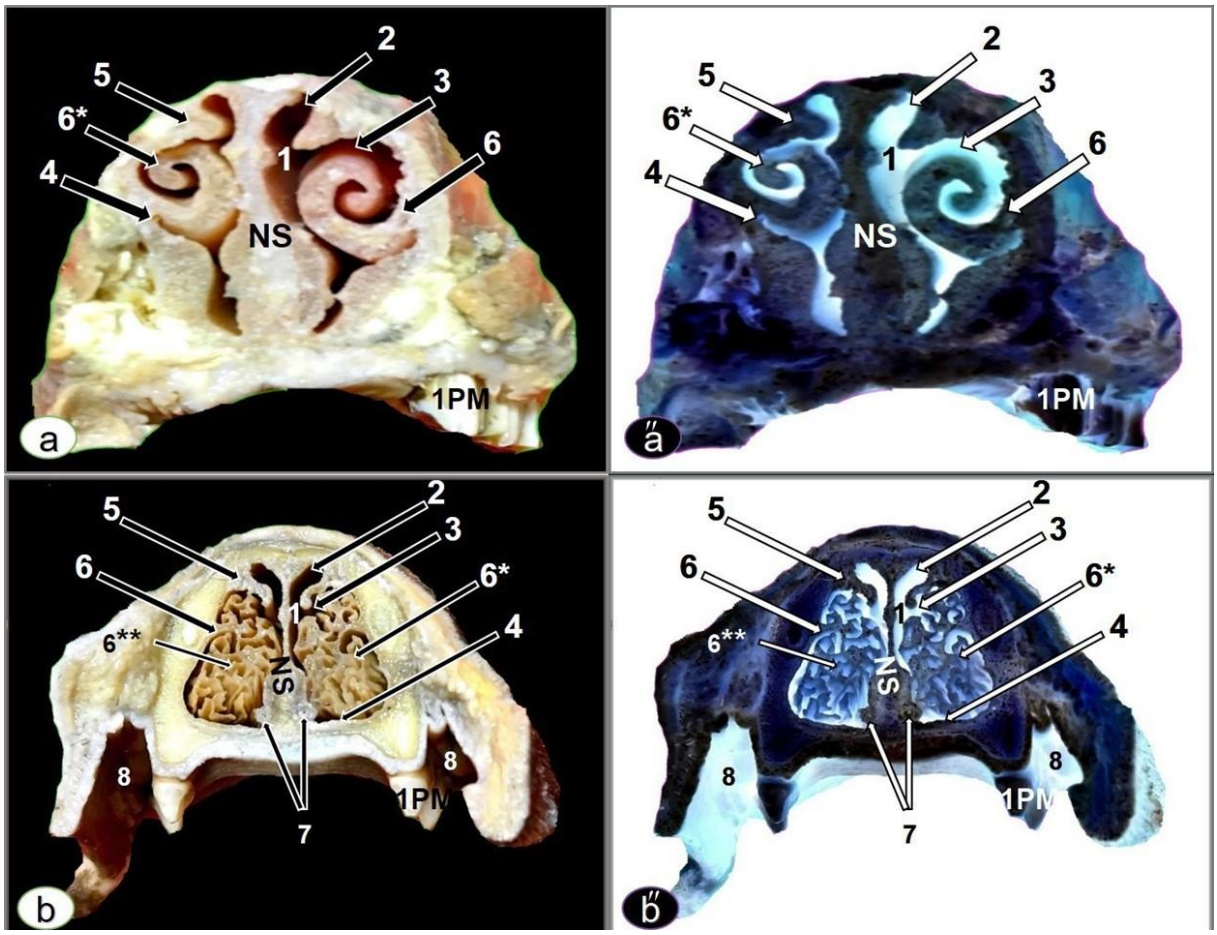

Fig. 5. Photographs of the cross section of the nasal cavity at the level of the caudal margin of the first premolar teeth (a) of goat, (b) of dog and (a" & b") their negative images, showing nasal septum (NS), first premolar teeth (1PM). 1- common nasal meatus, 2-dorsal nasal meatus, 3-middle nasal meatus, 4-ventral nasal meatus, 5-basal lamella of the dorsal nasal concha, 6-basal lamella of the ventral nasal concha, 6*-spiral lamella of ventral nasal concha, 6**- several secondary lamellae of ventral nasal concha, 7-vomeronasal organ, 8-buccal vestibule.

At the level of the caudal margin of the third premolar, in goat, the free border of the spiral lamella of the dorsal nasal concha was fused with the nasal bone forming the dorsal conchal sinus. The ventral nasal concha had the dorsal and ventral spiral lamellae. The dorsal spiral lamella was rolled 2 turns on itself enclosing a recess, while the ventral spiral lamella formed bulla. As well as, at this level in goat, the vomeronasal organ was clearly demonstrated on each side of the nasal septum, opposite to the palatine sinuses (Fig. 6a). In dog, the dorsal nasal concha consisted only of the basal lamella like that at the level of the first premolar teeth and the spiral lamella of the middle nasal concha was similar to that of the ventral nasal concha at the level of the first premolar teeth but the secondary spiral lamellae were thicker and larger (Fig. 6b).

At the last level, at the caudal margin of the first molar teeth, in goat, the dorsal and the middle nasal conchae were formed the dorsal and middle conchal sinuses. The dorsal conchal sinus was extended into the frontal sinus which was divided into the

medial and lateral frontal sinuses. Moreover, we observed at this level, the communication between the maxillary and palatine sinuses, and the partially division of the nasal cavity due to the separation of the caudal part of the nasal septum from the floor of the nasal cavity by a space, as well as the nasal septum became narrower than that observed at the previous levels (Fig. 7a). In dogs, this level was similar to the aforementioned level except the spiral lamellae less branched (Fig. 7b). All the morphometrical measurements of the nostril, the nasal septum, the nasal meatus, and the nasal concha (cm) were summarized in Table 1.

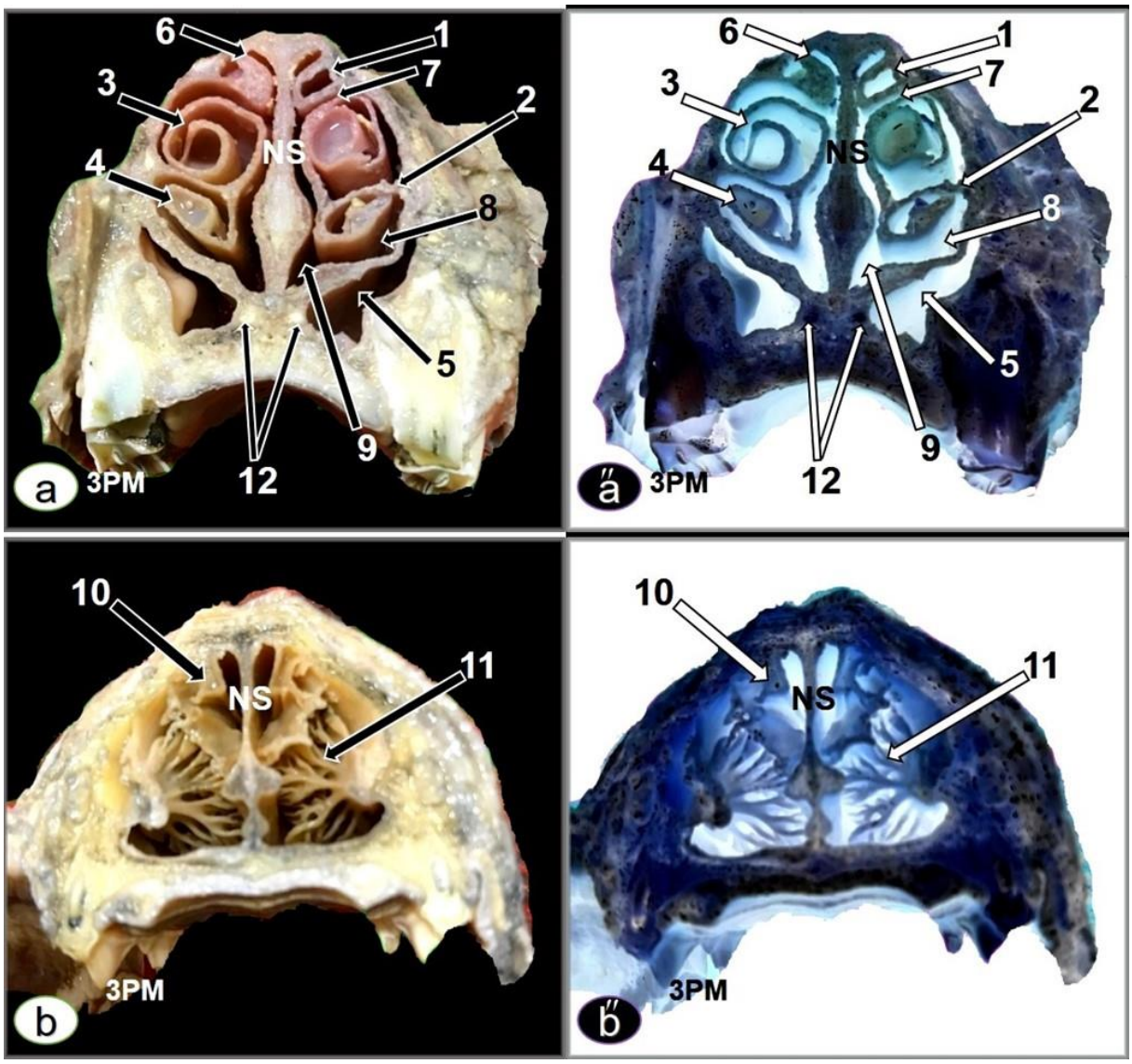

Fig. 6. Photographs of the cross section of the nasal cavity at the level of the caudal margin of the third premolar (a) of goat, (b) of dog and (a" & b") their negative images, showing nasal septum (NS), third premolar teeth (3PM). 1- dorsal conchal sinus, 2- basal lamella of the ventral nasal concha, 3- dorsal spiral lamella of the ventral nasal concha forming recess, 4- ventral spiral lamella of the ventral nasal concha forming bulla, 5- palatine sinus, 6- dorsal nasal meatus, 7- middle nasal meatus, 8- ventral nasal meatus, 9- common nasal meatus,10- dorsal nasal concha, 11-several secondary spiral lamellae of the middle nasal concha, 12-vomeronasal organ.

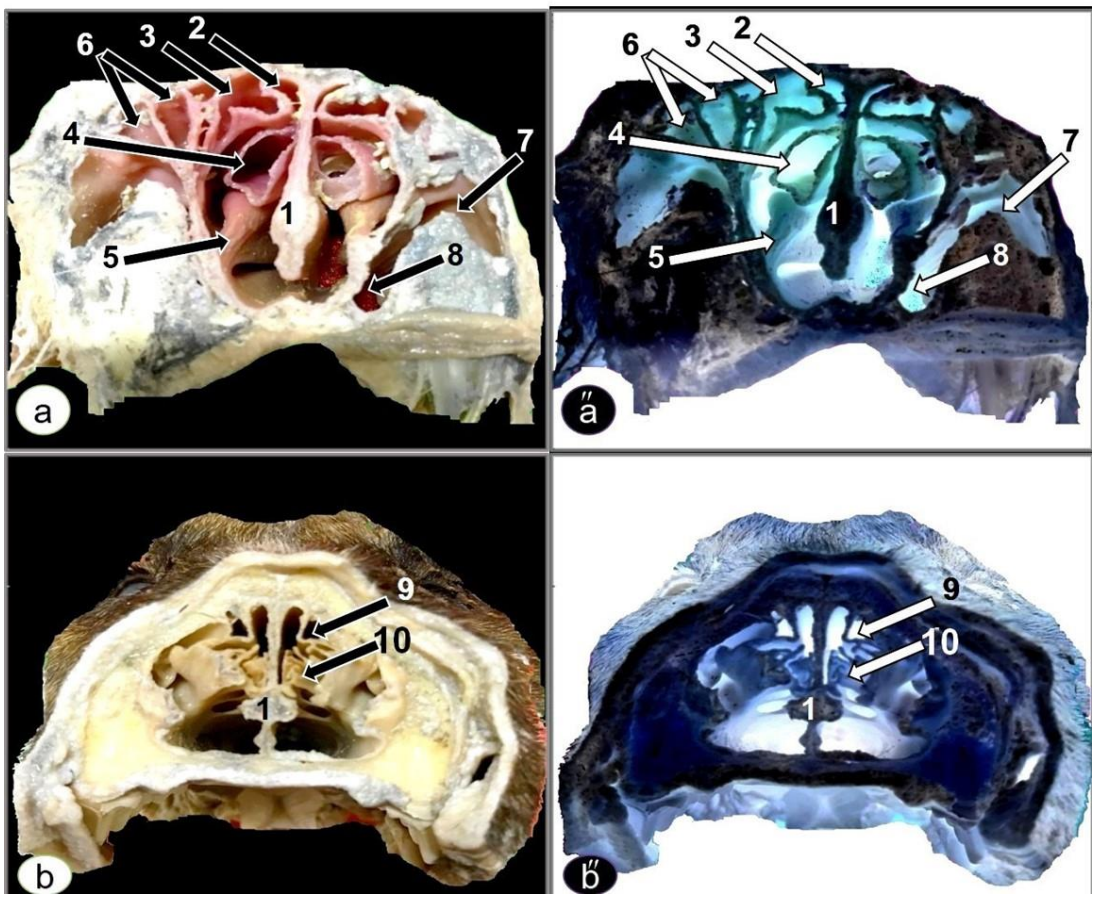

Fig. 7. Photographs of the cross section of the nasal cavity at the level of caudal margin of the first molar (a) of goat, (b) of dog and (a" & b") their negative images, showing 1- nasal septum, 2- dorsal nasal meatus, 3- dorsal conchal sinus, 4- middle conchal sinus, 5- ventral nasal concha, 6- medial and lateral frontal sinuses, 7-maxillary sinus, 8- palatine sinus, 9-dorsal nasal concha, 10- middle nasal concha.

Table 1. Morphometrical data (cm) of nostrils, nasal septum, nasal meatus, and nasal concha (mean ± SE).

Items	Egyptian goat	Egyptian baladi dog
Nostril: - Length	2.45 ± 0.10	2.1 ± 0.11
- Width	1.17 ± 0.14	1.18 ± 0.13
Length of nasal septum	14.6 ± 0.96	10.5 ± 1.08
Dimensions of nasal meatus:		
- Dorsal nasal meatus	0.54 ± 0.11	0.32 ± 0.14
- middle nasal meatus	0.54 ± 0.15	0.32 ± 0.25
- ventral nasal meatus	0.31 ± 0.14	0.47 ± 0.34
- common nasal meatus	4.57 ± 0.22	2.44 ± 0.35
Length of nasal conchae:		
- Dorsal nasal concha	10.53 ± 0.09	7.25 ± 0.10
- Middle nasal concha	5.13 ± 0.14	4.74 ± 0.24
- Ventral nasal concha	9.48 ± 0.10	4.67 ± 0.35
Width of nasal conchae:		
- Dorsal nasal concha	1.2 ± 0.26	0.44 ± 0.14
- Middle nasal concha	0.4 ± 0.65	0.57 ± 0.52
- Ventral nasal concha	2.3 ± 0.54	0.52 ± 0.43
-Distance between two nostrils	0.57 ± 0.9	0.82 ± 0.13
-Distance between nostril and tip of upper lip	1.42 ± 0.11	1.66 ± 0.14
-Length of straight fold	2.23 ± 0.14	2.35 ± 0.9
-Length of alar fold	3.18 ± 0.13	2.22 ± 0.12

Discussion

The current study revealed that the shape of the nasal cavity was typical cone-shaped in goat and a slight narrow elongated cone-shaped in dog, this result in dog agrees with the description of Nickel et al. (1979) in pig, while the result in goat is in accordance with Pathak and Rajput (2015) and Sharma et al. (1989) in Gaddi sheep, Naik et al. (2016) in Kenguri sheep. In contrast with the findings of El-hagri (1967) who mentioned that the nasal cavity of dogs is capacious with a great variability in length according to the breed. The latter author stated that the nasal cavity of the equines is a long and cylindrical passage. It is funnel shaped in buffaloes, camels and donkeys (Metwally et al., 2019). The difference in the shape of the nasal cavity among different species of the animals may be attributed to the modification of the upper jaw and the conformation of the head which play a role in estimation of the cavity' size.

The size and shape of the nostrils, their long axis, and the nature of the surrounding skin show considerable species differences. This study showed that the nostrils of goats were nearly horizontal slit-like in form, and somewhat comma-shaped in dog. In this connection, Metwally et al. (2019) reported that the nostril is comma-shaped, slit-like, crescentic-shaped in buffalo, camel and in donkey, respectively; however, the shape of the nostril of the latter animal is described comma-shaped by Elsaid et al. (2020). Budras et al. (2009) found that the nostril of horse is crescentic-shaped but during strong breathing, it dilates to become spherical in outline. Moreover, the nostril of pig is rounded (Dyce et al., 2018). The shape of the nostril is variable in the different animal species basing on the structure and the number of the nasal cartilages. The form of the nostril may also be altered by actions of the muscles of the face and by the increased airflow in strenuous breathing or sniffing (Dyce et al., 2018). The current statistical data indicated that the length of the nostril was greater than the width by two and a half fold in goat and by two folds in dog, but is greater by six folds in Gaddi sheep (Pathak & Rajput, 2015).

Based on the previous studies, the nasal septum was formed of cartilaginous part rostrally and bony part caudally, and completely divided the nasal cavity in dog, but as observed here, that the nasal cavity of goat was partially divided due to the caudal part of the nasal septum was separated by space from the floor of the nasal cavity. While, Alsafy et al. (2013) stated in the large ruminant (Egyptian buffalo) that the nasal septum reaches the floor of the nasal cavity. In this respect, the rostral third of the nasal septum of camel is a muco-muscular type (Badawi & Fateh El-Bab, 1974; Gewaily, 2009; Metwally et al., 2019).

The caudal end of the vomeronasal organs was found at the level of the first premolar teeth in dog, this is similar to that previously reported by Budras et al. (2003) in cattle. It was at the level of the third premolar in Egyptian goat as observed by Besoluk et al. (2001) in Angora goat and Metwally et al. (2019) and Fouad et al. (1984) in buffalo, but, Abbasi (2007) noticed the end of the vomeronasal organs in the latter animal at the level of the second cheek teeth. In donkey, the end of this organ is located at the level of the second premolar (Hamoda, 2000; Mansour et al., 2002; Metwally et al., 2019). Moreover, it was

reported at the fourth premolar teeth in camel (Metwally et al., 2019).

The arrangement of the nasal conchae in the domestic animals was documented in several books. In agreement with the finding that reported by Nickel et al. (1979), the dorsal, middle, ventral and ethmoidal conchae were present in goat and dog. However, El-hagri (1967) and Done et al. (2009) don't mentioned the presence of the ethmoidal concha in dog. The present results as well as Metwally et al. (2019) in donkey and buffalo, reported that the dorsal nasal concha was the longest concha. Conversely, the latter authors, Badawi and Fateh El-Bab (1974) and Gewaily (2009) clarified in camel that, the dorsal nasal concha is shorter and smaller than the ventral nasal concha.

Similar to buffalo (Moustafa & Kamel, 1971; Alsafy et al., 2013) and to cattle (Gadzhev, 1980), the transverse sectional anatomy of the head of goat revealed that the dorsal conchal sinus occupied the caudal third of the dorsal nasal concha, meanwhile, the middle conchal sinus occupied the caudal end of the middle nasal concha and the ventral conchal sinus was absent. As found here, there were no conchal sinuses in the studied dog, because the all portions of the conchae formed recess. Additionally, in line with the results of Nickel et al. (1979) in goat, the ventral nasal concha at the caudal third of the nasal cavity had the dorsal and ventral spiral lamellae and in dog the spiral lamella of the ventral concha was divided into several branching secondary lamellae, creating multiple narrow recesses.

Acknowledgment

The authors express their deepest gratitude to the members of the department of the anatomy and embryology, Faculty of Veterinary Medicine, South Valley University for their support.

Conflict of interests

All authors declare that there is no conflict of interests.

Financial disclosures

This work was not supported by any financial support.

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